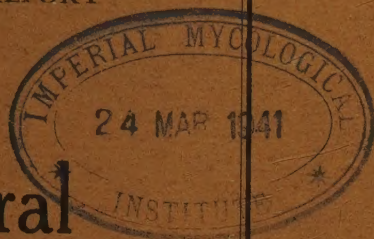


FIFTY-THIRD ANNUAL REPORT

OF THE

Agricultural Experiment Station



NOTICE

WITH THE ISSUANCE OF THIS VOLUME, THE
PART 2 SERIES OF THE ANNUAL REPORT OF
THE KENTUCKY AGRICULTURAL EXPERIMENT
STATION WILL BE DISCONTINUED.

▼
LEXINGTON

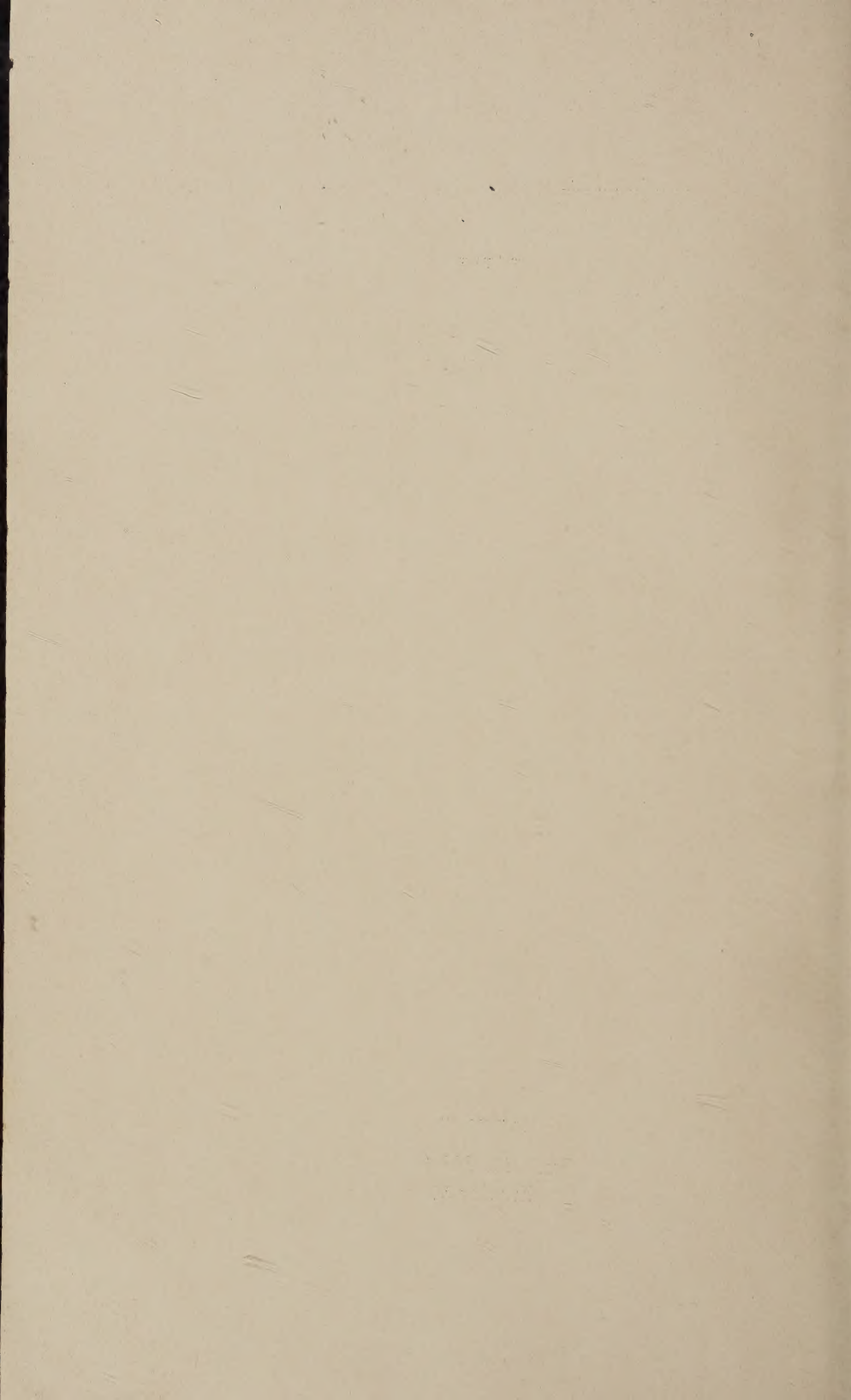
1940

FIFTY-THIRD ANNUAL REPORT
OF THE
**Kentucky Agricultural
Experiment Station**

FOR THE YEAR 1940



PART II
Bulletins 398-410
Circular 51



CONTENTS

Bulletins

No.		Page
398.	Wireworm injury to tobacco plants. H. H. Jewett	3
399.	Control of blackfire of tobacco in Western Kentucky. E. M. Johnson and W. D. Valleau	19
400.	The significance of biological types of <i>Salmonella typhi-murium</i> (<i>Salmonella aertrycke</i>). P. R. Edwards and D. W. Bruner	43
401.	Kentucky white grubs. P. O. Ritcher	73
402.	Reproductive efficiency in dairy cattle. F. E. Hull, W. W. Dimock, Fordyce Ely and H. B. Morrison	161
403.	Thirty years of farm prices and production in Kentucky. A. J. Brown and Dana G. Card	191
404.	Biochemical and serological studies of microorganisms of the <i>Salmonella cholerae-suis</i> group. D. W. Bruner and P. R. Edwards ...	291
405.	Variations in farm income and family living in Robertson County. John H. Bondurant and Max M. Tharp	307
406.	Cost of curing white Burley tobacco with artificial heat. Geo. B. Byers	335
407.	The effect of temperature and relative humidity during and after curing, upon the quality of white Burley tobacco. R. N. Jeffrey ...	355
408.	Distillery slop for hogs. E. J. Wilford	387
409.	Seasonal movements in prices and sales of Burley tobacco. Dana G. Card and Carl M. Clark	403
410.	The effect of nitrogen and phosphorus on the growth of apple and peach trees in sand culture. C. S. Waltman	489
	Subject index	551
	Author index	553

Station Circular

No. 51.	A key to Kentucky soils. P. E. Karraker and W. S. Ligon	
---------	---	--

Kentucky Agricultural Experiment Station

University of Kentucky

WIREWORM INJURY TO TOBACCO PLANTS

BULLETIN NO. 398



Lexington, Ky.

February, 1940

EXPERIMENT STATION STAFF

BOARD OF CONTROL

Richard C. Stoll, Chairman, Lexington, Ky.
James Park, Lexington, Ky.
H. S. Cleveland, Franklinton, Ky.
R. P. Hobson, Louisville, Ky.
Lee Kirkpatrick, Paris, Ky.

FRANK L. McVEY, President

THOMAS P. COOPER, Dean and Director

ADMINISTRATION

T. P. Cooper, Director
D. H. Peak, Business Agent
O. L. Ginocchio, Secretary

AGRONOMY

GEORGE ROBERTS, Head
Bortner, C. E., Asst. Agron.
Diachun, Stephen, Asst. Plant Path.
Fergus, E. N., Agronomist, Pasture and
Forage Crop Investgs.
Freeman, J. F., Asst. Agronomist
Henson, Lawrence, Asst. Forage Crops
Investgs.
Jeffrey, R. N., Plant Physiologist
Johnson, E. M., Asst. Plant Path.
Karraker, P. E., Agron. Soil Tech.
Kelley, J. B., Agricultural Engineer
Kinney, E. J., Agronomist, Tobc. and
Cereal Investgs.
Miller, Harold L., Asst. in Agron.
O'Bannon, L. S., Research Engineer
Rogers, T. Hayden, Asst. in Agron.
Valleau, W. D. Plant Pathologist
Weeks, Martin P., Asst. in Soils
Wyatt, C. E., Asst. in Soil Survey

ANIMAL HUSBANDRY GROUP

E. S. Goon, Chairman
Barber, Harold, Head Herdsman
Baute, E. A., Poultry Improvement
Buckner, G. D., In Charge Animal Nutrition
Ely, Fordyce, In Charge Dairy Husbandry
Garrigus, W. P., Asst. Animal Husb.
Harms, Amanda, Asst. Animal Nutrition
Hinton, Cecil M., Asst. Poultry Improvement
Insko, W. M. Jr., In Charge Poultry
Husbandry
Morrison, H. B., Jr., Asst. Dairy Husb.
Nutter, J. W., Dairyman
Ringrose, A. T., Poultry
Steele, Dewey G., In Charge Genetics
Watson, N. L., Cream Grading
Wilford, E. J., Swine, Meats

ANIMAL PATHOLOGY

W. W. DIMOCK, Head
Bruner, D. W., Asst. Bacteriologist
Edwards, Philip R., Bacteriologist
Errington, B. J., Pathologist
Hull, F. E., Asst. Veterinarian
Nolan, A. F., Asst. Pathologist
Phillips, Florence, Technician
Westerfield, Clifford, Asst. Veterinarian

CHEMISTRY

J. S. McHARGUE, Head
Averitt, S. D., Chemist
Hodgkiss, W. S., Assistant Chemist
Macy, Paul, Assistant Chemist
Ofutt, E. B., Assistant Chemist
Shedd, O. M., Chemist

CREAMERY LICENSE SECTION

J. D. FOSTER, Inspector, in Charge
Howard, N. J., Inspector

ENTOMOLOGY AND BOTANY

W. A. PRICE, Head
Deen, Encil, Seed Inspector
Didlake, Mary L., Assoc. Entgst.
Fried, Katharine, Seed Analyst
Jewett, H. H., Research Asst. Entgst.
Littell, Mary Lee, Seed Analyst
McDaniel, Alice, Seed Analyst
Morton, Margaret, Seed Analyst
Ritcher, P. O., Asst. Entgst.
Tilson, Howard G., Nursery Inspector
Vaughn, E. C., Seed Improvement

FARM ECONOMICS

W. D. NICHOLLS, Head
Allen, R. H., Land Economics
Beers, Howard W., Rural Sociology
Bondurant, J. H., Farm Management
Byers, Geo. B., Farm Organization
MacFarlane, David L., Farm Economics
Nesius, E. J., Farm Management
Oyler, Merton, Rural Life Studies
Williams, Robin, Rural Sociology

FEED AND FERTILIZER CONTROL

J. D. TURNER, Head
Allen, Harry, Chemist
Fitschen, Fred, Inspector
Gault, Lelah, Assistant Chemist
Mathews, Robert, Inspector
Rose, J. J., Microscopist
Spears, H. D., Senior Chemist
Terrell, W. G., Inspector

HOME ECONOMICS

STATIE ERIKSON, Head
Boyden, Ruth, Assistant

HORTICULTURE

A. J. OLNEY, Head
Armstrong, W. D., Horticulturist
Emmert, E. M., Assistant
Waltman, C. S., Assistant

MARKETS AND RURAL FINANCE

H. B. PRICE, Head
Binkley, Wendell, Markets
Brown, A. J., Prices and Statistics
Card, Dana G., Prices and Statistics
Clark, C. M., Markets and Finance
Phillips, C. D., Markets
Roberts, John B., Markets
White, Bennett S., Jr., Markets and
Cooperation
Wrather, S. E., Markets

PUBLIC SERVICE LABORATORIES

L. A. BROWN, Head
Fallis, R. W., Asst. Bacteriologist
McGuire, H. S., Jr., Asst. Bact.
Martin, James H., Asst. Chemist
Meader, A. L., Asst. Chemist
Terry, Geo. S., Bacteriologist

ROBINSON SUBSTATION (Quicksand, Ky.)

R. W. JONES, Superintendent
Wiggin, G. H., Forester

WESTERN KY SUBSTATION

(Princeton, Ky.)
S. J. LOWRY, Superintendent
Caldwell, L. M., Assistant

WIREWORM INJURY TO TOBACCO PLANTS

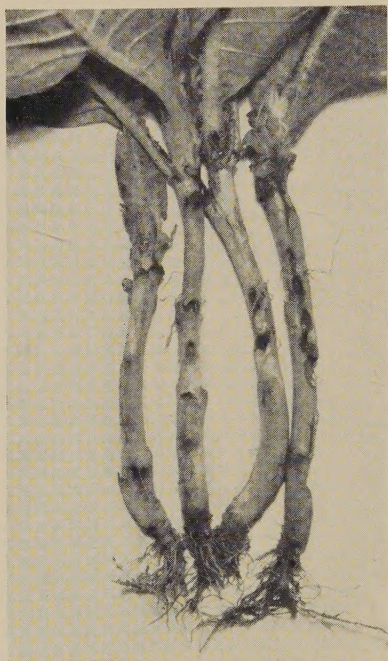
By H. H. JEWETT

The setting of tobacco plants is often followed by considerable injury by wireworms. The injury may be severe enough to cause the death of plants or it may weaken them to such an extent that they make slow growth. Sometimes considerable replanting has to be done where wireworm injury is severe or extensive. This is true, especially, where injury to plants occurs on the poorer soils. Several seasons of observation on wireworm injury have shown that on fertile soil only a small percent of plants die of injury and the irregularity in growth gradually disappears as the growing season advances.

The general practice of planting tobacco in rotations following sod conduces to wireworm injury because sod is a favorite habitat of several species of wireworms that may attack tobacco. When sod is plowed in preparation for tobacco, the worms are deprived of most of their food supply and they naturally attack any plant within reach. Following sod by tobacco is so general in the Bluegrass Region of Kentucky, however, that any other rotation would be difficult to put into practice, because experience of many years has demonstrated that it results in a large yield of tobacco of desirable quality.

Character and Extent of Wireworm Injury. Wireworms bore into and make tunnels in the stalks of tobacco plants. A tunnel may extend thru the entire length of the stalk and thru the bud, especially if the stalk is short. Wireworms often make exit holes from the tunnels, near the surface of the soil. Short-stalked plants are more likely to be severely injured because the buds are close to the surface of the soil. Slender plants do not withstand injury so well as larger plants. Tender plants are more severely injured than well-hardened plants. Injury by wireworms to young tobacco plants is often mistaken for sod webworm injury. Sod webworms generally eat into and partially girdle the stalks, or eat out portions, or burrow thru, or partially thru the stalks or buds. Sometimes they make partial tunnels in the stalks. Plants injured by sod webworms generally wilt more rapidly than those injured by wireworms, and are more likely to die.

The percentage of plants injured in experimental plots on the Experiment Station Farm varied considerably during the seasons,



Young tobacco plants showing wireworm injury to the stalks.

1935 to 1939, and was the greatest in 1938 when 61.1 percent of the plants were injured, table 1. Wireworms attack the plants as soon as they are set in the soil and injured plants can generally be detected by their wilted appearance. These may remain in an apparently dying condition for several days and it is at this time that the grower becomes alarmed and plans to re-set his field. The writer has observed, however, thru several seasons, that when the soil is fertile and suitable for growing good tobacco, very few plants die from wireworm injury. Records showing the number of plants under observation and the percentages killed are as follows: 1935, 4032 plants, 2.13 percent; 1936, 4114 plants, 2.85 percent;

1937, 4456 plants, 1.32 percent; 1938, 4238 plants, 1.11 percent; 1939, 3498 plants, 3.14 percent.

Wireworms Found Injuring Tobacco Plants. The species of wireworms found injuring tobacco plants in the Bluegrass Region of Kentucky are *Aeolus mellillus* (Say)*, *Conoderes auritus* (Hbst), *Conoderes bellus* (Say), and *Conoderes lividus* (De Gr). *Aeolus mellillus* (Say) is the most numerous and destructive species and *Conoderes auritus* next in importance. About 90 percent were *A. mellillus*. *Conoderes bellus* and *Conoderes lividus*, for several seasons at any rate, have been of no importance as pests of young tobacco plants. The writer has found no species of *Melanotus* injuring tobacco, altho an occasional specimen was taken by screening soil samples, and specimens in the Experiment Station collection are labeled as having been found injuring corn and tobacco. The

* This species is *Aeolus dorsalis* (Say) referred to in citations 1, 2 and 4.

four wireworms mentioned are very much alike in coloring, form, and size at different stages of development, and are not easy to differentiate. Descriptions of the four wireworms are given in a recent paper by the writer (1). *Aeolus millillus* (Say) and *Conoderes auritus* (Hbst) are the species considered in the following discussion of methods of control.

Aeolus mellillus (Say)

Larva. The larvae are small and range in length from 10 to 15 mm, with an average length of 11.7 mm. The width of the head ranges from .98 to 1.43 mm with an average of 1.18 mm. These measurements were for 10 mature larvae. The body is flattened dorso-ventrally and tapers slightly toward the extremities. The surface of the body is smooth and sparsely hairy. The color is yellow, with the head, dorsum of the first thoracic segment and sometimes a part of the second segment, tubercles on the ninth abdominal segment and tips of the processes, reddish brown. The mandibles, and spines on the anal proleg, are dark brown.



Aeolus mellillus (Say) six times natural size.

Seasonal History. *Aeolus mellillus* is quite numerous in the Bluegrass Region of Kentucky and is the dominant species as a pest of tobacco. It is an important pest of corn in some regions. The life history is imperfectly known. The adults appear in the late summer and early fall and in the spring and early summer, in largest numbers, but adults have been found emerging from pupae from April 20 to November 11. Both adults and larvae live over winter, the adults hibernating under a variety of litter on the ground. By sifting soil in the late summer and fall, larvae in different stages of development were found. A part of these pupated and emerged as adults the same season, pupation being mainly completed by September 15, the latest taking place October 4. Pupation of larvae collected in the spring may begin as early as April 8. Collections were made in the late summer and fall, from 1934 to 1938, and in the spring, from 1935 to 1939, and in no in-

stance did immature larvae collected in the fall or spring, of which records were kept, fail to mature during the following spring and summer seasons. This indicates a developmental period of one

year. Bryson (2) states that the larvae develop in one year. Adults that emerge from pupae in the spring may live for several weeks, June 14 to September 5 being the longest period recorded. This long adult period indicates a long egg-laying period.

Conoderes auritus (Hbst)

Larva. The color is practically the same as that of *A. mellillus*. The body is flattened and tapers to the head from the thorax but there is slight tapering of the abdominal segments, the ninth being the smallest. The body is smooth and shining, with few hairs. The average length of 10 larvae was 12.5 mm. The average width of the head was 1.27 mm, the range 1.15 to 1.33 mm. This wireworm is only slightly larger than *A. mellillus* and because of similarity in form and color may easily be mistaken for that species.

Seasonal History. The seasonal history of this wireworm is similar to that of *A. mellillus*. Both adults and larvae live over winter.

Some of the worms mature in late summer and fall, pupate, and the adults emerge the same season; others live over winter. Pupae have been found from April 25 to September 21, from which adults emerged from May 2 to November 5. Adults are more numerous in the spring and early summer and in the fall. In no instance did worms collected in the fall or spring live thru the second season, which indicates that worms develop within one year. Adults that emerge from pupae in spring may live for a long time, June 7 to October 6, 1939, being the longest period observed here.

WIREWORM POPULATIONS IN RELATION TO PLANT INJURY

The wireworm populations of bluegrass sod were estimated by examining samples of soil and sod each year, in the fall previous to planting tobacco. The records are summarized in table 1. Each



Larva of *Aeolus mellillus*, six times natural size.

unit, or sample, examined was 1 foot wide, 3 feet long and 8 inches deep. The sod was torn apart and the soil sifted thru screens to separate the worms. Thirty or 36 samples were examined from plots of bluegrass sod one-half acre in size. The number of wireworms per acre from 1934 to 1936 did not vary greatly, but was con-

Table 1. Number of wireworms in bluegrass sod which was followed the next spring by tobacco, and amount of injury to the tobacco. Samples of soil for counts were 1 foot by 3 feet by 8 inches deep.

Counts made	Number of samples	Number of worms per acre	Average percent of plants injured	Crop of
Sept. 1934	30	34354	31.2	1935
Sept. 1935	36	37510	24.6	1936
Sept. 1936	30	31944	22.9	1937
Sept. 1937	36	59290	61.1	1938
Sept. 1938	30	65340	56.9	1939

siderably larger in 1937 and 1938. Variations in percentages of plants injured approximated the changes in wireworm populations. The land used for tests in 1935 to 1938 had been in sod for a long time. That used in 1939 had been in sod from seed sown early in the fall of 1934. The changes in wireworm populations in the new sod during that time are interesting. In 1934 there were 7260 worms per acre; in 1935, 10290; in 1936, 18150; in 1937, 32670; in 1938, 65340. Within three full-years, the population was practically one-half that in the old sod, and in four years equaled that of old sod. Old sod in 1938 had a population of 61710 worms per acre.

CONTROL OF TOBACCO WIREWORMS

Wireworms, the young of Elateridae, or click beetles, do a great deal of damage to crops in general and much has been written about them and their control. C. A. Thomas (3) gives references on the economics of these insects and a summary of results obtained from various control measures. Many insecticides have been tried for controlling wireworms, but in general they have given poor results or have proved too costly for use except on a small scale. Because of this fact, control will probably have to be effected by the use of some farm or cultural practice.

In the Bluegrass Region of Kentucky, the most important tobacco wireworm is *Aeolus mellillus* (Say). Bluegrass sod is a favorite habitat of this species and since much of the land is kept in sod, there is an abundance of this wireworm every season. Tobacco

commonly follows sod in rotation and after this crop has been removed, grain or grain and grass, so that the soil is never free of wireworms. For several seasons, the writer has tried a number of farm and cultural practices to determine their value, if any, in reducing wireworm injury to tobacco. Single and replicated tests of several were made.

Practices Followed. The following practices were tried: (1) fall plowing compared with spring plowing of sod land; (2) setting plants upon slight ridges; (3) setting plants in slight furrows; (4) setting plants at one-half normal spacing, compared with normal spacing; (5) the use of fertilizer to stimulate quick growth; (6) the use of different types of plants; (7) the use of different strains of white burley tobacco; (8) repeated cultivation of the soil at different depths previous to setting the plants; (9) setting the plants on progressively later dates; (10) a two-year rotation of tobacco.

General Procedure. The sod land available for use was limited, so that the plots were only one-sixtieth of an acre. During 1935 to 1938, single plots were used for each test, with several check plots for comparison. In 1939 certain of the practices were replicated five times, with an equal number of check plots. The fall plowing was done in November and spring plowing in March. The plants were set by machine on the same day except when different dates are indicated. The plantings were examined at regular intervals for the purpose of observing the condition of the plants and recording the number that died from wireworm injury. After the normal time for setting plants had passed, about July 1, those in the plots were pulled and examined for wireworm injury.

EFFECT OF THE PRACTICES TRIED

Fall Plowing. There is considerable difference of opinion among workers as to the effect of late fall and early winter plowing upon wireworms. In regard to *Aeolus mellillus*, Forbes (4) states that fall plowing commended as a general defense against wireworm attack, would probably be without effect against this species. He based his conclusion on the supposition that the larvae live two years before pupation, and that the adults hibernate in sheltered places. The larvae of *A. mellillus* are found above the plow line in fall and early winter and would be subjected to adverse factors by fall plowing. The effect on larvae of *A. mellillus* was determined by comparing the numbers of injured tobacco plants that had been set

on fall-plowed and spring-plowed plots. Results of the tests with single plots are summarized in table 2 and of the series test in table 9. Fall plowing was of no benefit in reducing wireworm injury during the several seasons this practice was used. As a matter of fact, a slightly greater percent of plants, in the fall-plowed plots, were injured, except in 1938 than in the spring-plowed plots. In 1937, about 11 percent more plants were injured in the fall-plowed plot than in the spring-plowed plot.

Table 2. Wireworm injury to tobacco plants on fall-plowed and spring-plowed land.

Crop of	Percent killed		Percent killed and injured		Number of plants examined	
	Fall plowed	Spring plowed	Fall plowed	Spring plowed	Fall plowed	Spring plowed
1935	3.1	1.8	39.0	33.1	162	169
1936	3.8	1.4	19.7	14.5	157	152
1937	2.8	2.7	34.3	23.4	143	146
1938	0.3	1.9	65.4	67.5	142	157
Average	2.5	2.0	39.6	34.6	151	156

Plants Set on Ridges and in Furrows. Plants were set on ridges about 4 inches high and in furrows about 4 inches deep. Fewer of the plants set on ridges were injured than of those set in furrows. The difference was practically 10 percent in favor of ridge planting. Compared with the checks for the same year, the difference was only slightly less in favor of ridge planting, table 3. In replicated plots

Table 3. Wireworm injury to tobacco plants set on low ridges, in shallow furrows, and as usual.

Crop of	Percent killed			Percent killed and injured			Number examined		
	On ridges	In furrows	As usual	On ridges	In furrows	As usual	On ridges	In furrows	As usual
1935	1.2	1.2	1.8	19.3	29.2	29.6	166	164	169
1936	0.6	4.5	2.7	15.6	24.2	23.5	160	157	149
1937	0.7	0.0	2.8	12.5	22.5	23.6	152	142	144
1938	2.1	0.7	2.6	57.1	69.9	62.2	154	153	156
Average	1.2	1.6	2.5	26.1	36.5	34.7	158	154	155

in 1939, 6 percent fewer plants set on ridges were injured than in the check plots.

Plants Set at One-half Normal Spacing. The use of extra plants is often the only practice that helps to get a crop in fields where wireworms are destructive. When plants were set at one-half nor-

mal spacing, too many plants were left in the rows, even after some had been killed by wireworms and the more severely injured had been pulled. Also, the plants remaining were too irregularly spaced for the production of good tobacco. The percentages of plants injured, in rows where the plants were set at one-half normal spacing, differed little from those for normal spacing, or checks, table 4.

Table 4. Wireworm injury to tobacco plants set the normal distance apart in the row, and half that distance.

Crop of	Percent killed		Percent killed and injured		Number examined	
	Half spacing	Normal spacing	Half spacing	Normal spacing	Half spacing	Normal spacing
1935	2.5	1.2	22.5	23.7	160	160
1936	1.5	2.1	20.8	21.6	159	162
1937	2.8	1.3	21.5	18.1	144	149
1938	1.8	2.6	59.5	62.2	142	156
Average	2.2	1.8	31.1	31.4	151	157

Fertilizers. Fertilizers frequently have been recommended as insecticides for the control of wireworms. In most instances, however, their chief benefit is from the stimulating effect upon the plants, causing them to overcome injury and maintain normal growth. Thomas (3, p 39) advises the use of cultivation and fertilization to stimulate crops and keep them growing. Hawkins (5, p 104) con-



The two small plants in the foreground were injured by wireworms. In fertile soil these plants will recover and cannot be distinguished from other plants at harvest time.

cludes from his experimental work that fertilizer has no apparent effect on preventing wireworm injury to potatoes after they are formed in the soil.

For two seasons sodium nitrate was applied on plots shortly after the plants had been set. The soil was fertile and no apparent benefit was derived from the use of the fertilizer. The percentage of injured plants was practically the same as in the unfertilized plots. The percent of plants killed and injured on treated plots was 31.7 in 1935 and 35.2 in 1936, while the percent of plants killed and injured on the check plots was 34.9 in 1935 and 32. in 1936.

Size of Plants. Tobacco plants are attacked by wireworms soon after they are set in the field but they can withstand severe injury



Four groups of tobacco plants with stalk diameters of 5, 6, 7 and 8 mm (about $\frac{1}{3}$ natural size). Plants of the 7 mm size, or larger, are much more resistant to wireworm injury than the smaller sizes.

and recover. The size of the plants has much to do with recovery and growth after injury. For four seasons, plants of four sizes were used to observe their relative resistance to injury. The diameters of the stalks of the plants approximated 5, 6, 7, 8 mm. The plants with stalks of 5 and 6 mm diameter recovered more slowly from injury than the larger plants and more died from injury but the per-

centage killed was not much greater than in the larger sizes. The growth of the small plants was noticeably less than that of the large plants, especially on the poorer soils. In plots of the smaller plants, the growth was much more irregular. Plants with stalks about 7 mm in diameter or the size of a lead pencil, seemed to be the best. The stalk should be long enough so that, in setting, the soil does not cover the bud nor come too close to it. It was noticeable that when the plants were set too deep there was much injury to the buds, because wireworms work near the surface of the soil. Records of injury to different sized plants are summarized in table 5.

Table 5. Wireworm injury to different sized tobacco plants.

Crop of	Percent killed				Percent killed and injured				Number of plants counted			
	Diameter of the stalk				Diameter of the stalk				Diameter of the stalk			
	5 mm	6 mm	7 mm	8 mm	5 mm	6 mm	7 mm	8 mm	5 mm	6 mm	7 mm	8 mm
1935	4.2	2.5	1.2	2.6	31.1	30.4	32.7	25.9	168	161	165	160
1936	3.9	3.8	1.3	1.3	38.2	26.9	29.3	22.1	152	156	164	160
1937	2.1	2.7	2.1	1.4	23.1	26.8	23.4	24.8	143	142	145	143
1938	3.2	1.9	1.3	1.3	61.3	60.3	62.7	63.5	160	158	161	155
Ave.	3.4	2.7	1.5	1.7	38.4	36.1	37.0	34.1	156	154	159	155

Different Strains of White Burley. Four different strains of white burley tobacco, Judy, Kentucky 5, Kentucky 7 and Kentucky 16, were used in four seasons, to test difference in resistance to wireworm injury. There was no significant difference in the number of plants injured, or that died from injury, in favor of any strain used, table 6.

Table 6. Wireworm injury to different strains of white Burley tobacco.

Crop of	Percent killed				Percent killed and injured				Number of plants examined			
	Judy	Ky. 5	Ky. 7	Ky. 16	Judy	Ky. 5	Ky. 7	Ky. 16	Judy	Ky. 5	Ky. 7	Ky. 16
1935	2.6	1.8	1.3	1.9	25.9	33.1	25.6	23.1	162	169	156	156
1936	1.3	1.7	5.5	3.3	22.1	23.5	21.4	21.9	154	149	156	151
1937	1.4	1.5	1.5	1.4	24.8	26.8	28.3	22.6	141	134	135	146
1938	1.3	1.3	1.3	1.9	62.5	66.9	55.9	56.3	154	144	158	158
Ave.	1.7	1.6	2.4	2.1	33.8	37.6	32.8	31.0	153	149	151	153

Cultivation. A considerable number of investigators have recommended cultivation as a method of wireworm control. Some sort of cultivation has been suggested for every season of the year. The object of the various recommendations, such as plowing or cultivating at certain seasons, is mainly to expose the insect in its different stages of development to unfavorable weather conditions, to

deprive it of food, or otherwise to create an unfavorable environment. Most of the recommendations for control are based on observations or experience of growers. Rawlins (6) concludes from his study of the wheat wireworms, *Agriotes mancus* (Say), that marked decreases in larval populations result from continued cultivation of infested fields. Hawkins (5) states that clean cultivation is a practical control measure for wireworms, a conclusion based on experimental work with *Agriotes mancus* (Say).

The preparation of sod land for tobacco includes plowing in the fall or spring, followed, in the spring, by disking and dragging to get the surface soil fine and smooth. Cultivation is limited because of the nature of the crop. Fall plowing does not reduce injury by the wireworms, *Aeolus mellillus* (Say) and *Conoderes auritus* (Hbst) because these wireworms are active and when brought to the surface by cultivation remain exposed only a short time. In order to determine the effect of cultivation on the amount of wireworm injury to tobacco, certain plots were given five cultivations to depths of 2 and 4 inches, before the plants were set, in addition to the usual preparation of the land. The cultivations were made on bright days. The percentages of injured plants in the season, 1935 to 1938, were slightly less in the plots cultivated 4 inches deep than in those cultivated 2 inches deep; however, only in 1938 did extra cultivation appear to be of much benefit. That season the number of injured plants was about 18 percent less in the cultivated plots than in the checks. In 1939, extra cultivating, before setting the plants, was of some benefit. Plots so treated had an average of 6.9 percent fewer injured plants than the check plots, tables 7 and 9.

Table 7. Wireworm injury to tobacco plants on plots given five cultivations before setting, in addition to the usual preparation of the land.

Crop of	Percent killed			Percent killed and injured			Number plants examined		
	Cultiva- tion 2" deep	Cultiva- tion 4" deep	Usual prepar- ation	Cultiva- tion 2" deep	Cultiva- tion 4" deep	Usual prepar- ation	Cultiva- tion 2" deep	Cultiva- tion 4" deep	Usual prepar- ation
1935	2.0	3.3	2.5	34.6	27.8	35.8	153	151	162
1936	2.8	2.0	2.5	25.9	22.6	31.4	143	155	159
1937	2.7	1.4	0.7	25.8	21.9	26.7	146	146	135
1938	0.6	0.6	2.6	47.4	42.7	60.0	158	157	156
Average	2.0	1.8	2.1	33.4	28.8	38.5	150	152	153

Different Setting Dates. The larva of *Aeolus mellillus* and *Conoderes auritus* begin pupating in the spring, and for that reason

tobacco plants were set at successively later dates to see if there was a time when wireworm injury decreased to any considerable extent. The settings were made at about weekly intervals. It was found that the later set plants did escape considerable wireworm injury and that the drop in injury took place rather abruptly. This change took place on June 20 in 1935 and 1936, June 17 in 1937, June 6 in 1938 and June 16, in 1939. It appears that about June 15 is the earliest date on which tobacco can be set with a prospect of escaping considerable wireworm injury. That date is a little late for the general setting of tobacco plants, but possibly this information may be useful in connection with other crops attacked by the larvae of *A. mellillus* which would be benefited by delayed planting. The records of injury to plants set on different dates are summarized in tables 8 and 9.

Table 8. Percent of tobacco plants set on different dates, killed and injured by wireworms.

Settings		1st	2nd	3rd	4th	5th
1935	May 30, June 6, 13 and 20	25.9	26.8	24.2	15.6	
1936	May 22, June 1, 8, 13, and 20	31.2	27.5	26.4	28.4	6.10
1937	June 1, 8, 17 and 24	30.3	29.4	15.7	12.1	
1938	May 28, June 6, 15 and 21	59.1	39.9	31.7	23.6	

Tobacco Two Years in Succession. Since tobacco is frequently planted for two seasons in succession, after sod, it is of interest to know the amount of injury the second year. The percentage of injured plants in 1935 on one plot was 29.4 and in 1936, 11.8; on one plot in 1936, 23.6 and in 1937, 13.7; on one plot in 1937, 26.6 and in 1938, 24.4. The percentage of plants injured the second year on two plots was approximately one-half that for the first year and for one plot practically the same. Rye was used as a winter cover crop following tobacco.

Series Tests. Some of the practices that were tried on single plots in 1935 to 1938 were given more extensive trials in 1939. There were 5 replications of each practice and 5 checks, or untreated plots. All plots were plowed in the spring except the 5 plowed in the fall. The practices employed were: fall plowing, extra cultivation before setting the plants, setting plants on slight ridges, setting plants on successively later dates, spring plowing as checks. The results are summarized in table 9.

Fall Plowing. The plants on the fall-plowed plots were set

on June 2. For the 5 plots, the average percent of plants injured was 62.5. This percentage was slightly greater than that for the spring-plowed plots, or checks.

Table 9. Percent of tobacco plants under different treatments, killed and injured by wireworms. Five replications of 106 to 124 plants each. Crop of 1939.

Treatments	Replications					Average
Fall plowing, set June 2	45.3	71.2	62.4	70.4	63.2	62.5
Spring plowing, set June 2	46.3	38.3	72.0	73.0	54.7	56.9
Spring plowing, set June 9	44.4	47.4	43.7	30.2	35.8	40.3
Spring plowing, set June 16	24.8	30.2	27.7	34.2	35.5	30.5
Extra cultivation, set June 2	41.9	38.5	55.2	61.2	53.4	50.0
Ridge planting, set June 2	41.2	46.2	52.1	59.3	55.7	50.9

Cultivation. The average percent of plants injured was 50.0, on the plots that were given 5 cultivations in addition to the regular preparation of the land for setting plants. The cultivations were made with a disk harrow, 4 inches deep. Apparently wireworm injury was reduced somewhat but the difference in favor of cultivation was not great.

Ridge Planting. Setting plants on slight ridges resulted in some reduction of wireworm injury. The percent of plants injured was practically the same where plants were set on ridges as where frequent cultivations were given.

Time of Setting Plants. The date on which plants were set had more effect on wireworm injury than any other practice used. The check plots set on June 2 had 56.9 percent of the plants injured, while plots set on June 9 had 40.3 percent injured, and those set on June 16 had 30.5 percent injured. There was a considerable reduction in percentages of plants injured in favor of the later dates.

SUMMARY

The wireworms, *Aeolus mellillus* and *Conoderes auritus*, are the two most important wireworm pests of tobacco in the Bluegrass region of Kentucky. *Aeolus mellillus* is the dominant one, about 90 percent being of that species.

Wireworm injury to tobacco is often mistaken for sod webworm injury, because the two pests attack tobacco plants during the same time. Wireworms generally tunnel into the stalks and sod webworms eat into or cut the stalks somewhat in the manner of cutworms.

The percentages of plants injured by wireworms during the seasons of 1935 to 1939 varied from 22.9 to 61.1 and the percentages of plants killed, from 1.1 to 3.1.

Tobacco plants can recover from severe injury but recovery is slower and subsequent growth much more irregular on poor than on fertile soil.

The population of wireworms in new bluegrass sod increased rapidly and in three years was more than one-half as large as that in old sod and in four years was equal to that in old sod.

Wireworm injury to tobacco plants was not reduced by fall plowing, but thoro cultivation before setting the plants reduced injury slightly. Thoro cultivation had the added benefit of getting the soil in excellent condition for setting plants.

The size and type of plants has much to do with resistance to wireworm injury. Small, slender plants recovered slowly from injury and made irregular growth. Tender plants were not as satisfactory as hardened plants. Short plants were more likely to be injured in the buds. Plants with stalks the thickness of a lead pencil, or larger, recovered from injury more quickly than smaller plants.

A greater percent of plants were injured when set early than when set late. Very little difference occurred till about June 15, or a few days later, when there was a reduction of about one-half in the percentage of injured plants.

LITERATURE CITED

1. Jewett, H. H. 1939. Four Wireworms found in Bluegrass Sod, Ky. Agr. Exp. Sta. Bull. 392.
2. Bryson, Harry R. 1930. A Study of Field Practices as Related to Wireworm Infestations. Jr. Econ. Ent. 23:313.
3. Thomas, C. A. 1930. A Review of Research on the Control of Wireworms. Pa. Agri. Exp. Sta. Bull. 259.
4. Forbes, S. A. 1891 and 1892. Eighteenth Report of the State Entomologist of Noxious and Beneficial Insects of Illinois.
5. Hawkins, John H. 1936. The Bionomics and Control of Wireworms of Maine. Me. Agr. Exp. Sta. Bull. 381.
6. Rawlins, W. A. 1934. Experimental Studies on the Wheat Wireworm, *Agriotes mancus* Say. Jr. Econ. Ent. 27:314.

Kentucky Agricultural Experiment Station

University of Kentucky

CONTROL OF BLACKFIRE OF TOBACCO IN WESTERN KENTUCKY

BULLETIN NO. 399



Lexington, Ky.

February, 1940

CONTENTS

	PAGE
Names and descriptions of the diseases	19
Wildfire and angular leafspot damage plants in the bed	21
Bordeaux controls wildfire and angular leafspot in the bed ...	22
Bordeaux treatment of tobacco beds helps in the control of blackfire	24
Use of plants affected with wildfire or angular leafspot is inad- visable	26
Borrowing plants is not advisable	27
Blackfire and soil fertility	29
Manure helps to prevent blackfire losses	29
Soils of the dark-tobacco area often are low in fertility	32
Good soil management is necessary for profitable production of dark tobacco	34
Discussion	36
Summary	37

**CONTROL OF BLACKFIRE OF TOBACCO
IN WESTERN KENTUCKY**

By **E. M. JOHNSON** and **W. D. VALLEAU**

In Western Kentucky, during periods of frequent or heavy rains, dark tobaccos may be damaged greatly by leafspot diseases variously known as wildfire, angular leafspot, rust, and blackfire. Usually most of the injury occurs after topping and suckering. These diseases cause some loss every year, even when rainfall is below normal, as in 1936 and 1939, when losses as great as 25 percent occurred. In 1937, when rainfall in the latter part of the growing season was slightly above normal, more fields were affected and losses were as great as 50 percent on some farms. In 1938, when rainfall was abnormally high during the latter half of the growing season, many fields were destroyed and at least 50 percent of the dark tobacco crop was lost.

NAMES AND DESCRIPTIONS OF THE DISEASES

In this bulletin the terms wildfire and angular leafspot will be used only for infections on plants in the bed or on tender, rapidly growing plants in the field, where the two kinds of spots are readily distinguishable. Those caused by *Bacterium tabacum*, known as wildfire, are usually circular, dead spots surrounded by a distinct broad, yellow border, or halo. Infections with *Bact. angulatum*, known as angular leafspot, usually are angular and brownish and have no pronounced halo (figure 1). The typical spots can be produced on vigorously growing plants by spraying the leaves with a suspension of the respective bacteria in water, the only requirement being that the stomata are open and bacteria enter the leaf.¹ The term "blackfire" will be used for the late-season spotting of tobacco which occurs after topping and suckering. The disease is characterized by the presence on the leaves of dead, brown, zonate spots of various shapes, 1/4 inch to several inches in diameter. The spotting is caused by a combination of wet weather, low soil fertility

1. Diachun, Stephen. Relation of stomata to wildfire infection. *Phytopathology* 30: 268-272. 1940.

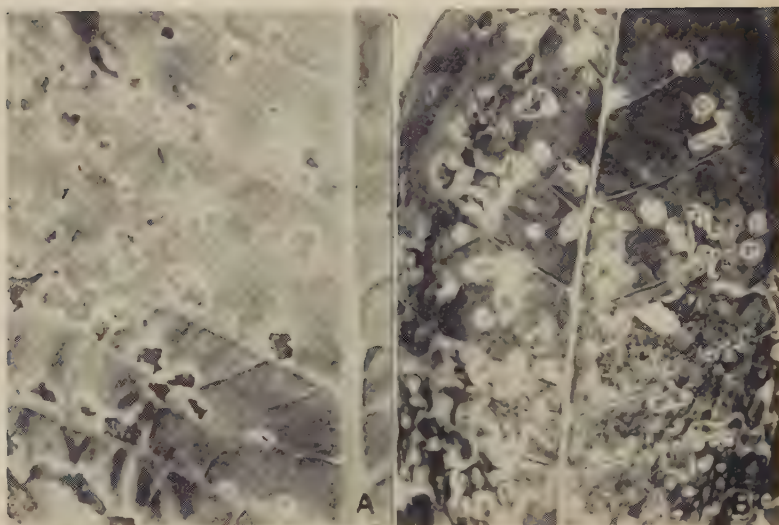


Figure 1. Recent infections of wildfire and angular leafspot on tender, young tobacco leaves. A. In angular leafspot the spots are usually brownish, angular, dead areas without conspicuous halos. B. Wildfire spots are usually circular, dead areas with conspicuous halos.

and infection with either *Bacterium tabacum* or *Bact. angulatum* (figure 2). It has not been possible to produce this type of spot by simply inoculating the leaves of topped plants with the wildfire or angular leafspot organisms. The plant must be susceptible and



Figure 2. Blackfire on dark tobacco after topping. A. Large, zonate dead spots are typical of the late-season disease. B. Blackfire spots often cover the entire surface of leaves and makes them worthless. C. Sometimes all the leaves of a plant are affected with blackfire and the plant appears scorched.

the leaves must be wet by dew or rain during several successive nights.²

WILDFIRE AND ANGULAR LEAFSPOT DAMAGE PLANTS IN THE BED

In springs when rainfall is high and temperature low, wildfire or angular leafspot may be destructive to small tobacco plants in the bed. Under these conditions tobacco plants the size of a dime to a dollar, if attacked, develop a wet rot and often die (figure 3). In 1937 and again in 1939 many beds were seen where half the plants were killed by either or both wildfire and angular leafspot. In both

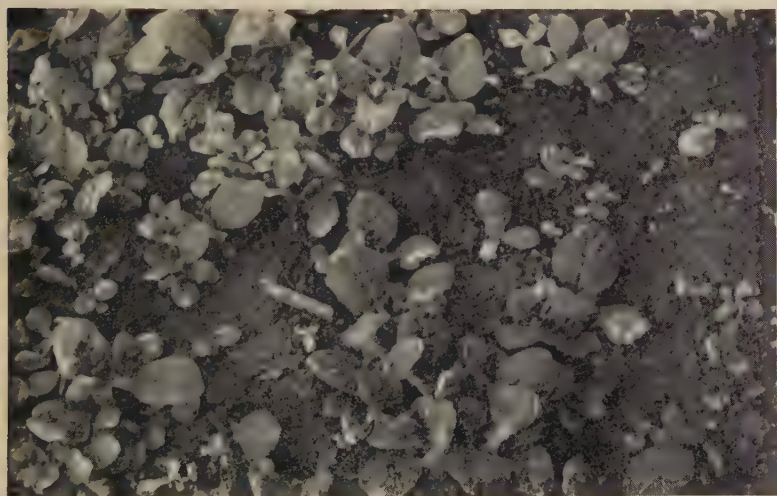


Figure 3. Wildfire damage to small tobacco plants in the bed. Small seedlings from the size of a dime to a dollar are sometimes killed. About half the plants in this bed were killed and growth of larger plants was retarded. Growers often confuse this type of injury with that of blue mold.

these years these diseases were markedly more destructive than blue mold. The diseases affect plants, from an inch to three or four inches in diameter, which are making rapid, tender growth just after they have become well established. Half-grown or larger plants are rarely killed by wildfire or angular leafspot but their growth may be retarded (figure 4).

² Johnson, E. M., Stephen Diachun, and W. D. Valleau. Experimental production of Blackfire on Tobacco. *Phytopathology*. 30: 73-79, 1940.

BORDEAUX CONTROLS WILDFIRE AND ANGULAR LEAFSPOT IN THE BED³

Studies by the writers and others have failed to reveal the life histories of *Bact. tabacum* and *Bact. angulatum*. Angular leafspot appeared in the Station tobacco beds at Lexington almost every year and in some years an occasional spot of wildfire was present altho the usually recommended precautions to prevent them were



Figure 4. Wildfire on a tobacco plant nearly ready to set. Plants half grown or larger are rarely killed but their growth may be retarded.

followed, such as seed treatment, use of new or boiled cotton, new bed sites, new bed frames, avoidance of the use of diseased, cured tobacco and so on. For several years Bordeaux mixture has been used on tobacco beds at Lexington and Princeton and infection with wildfire or angular leafspot has been almost entirely prevented in the bed and blackfire has been controlled or reduced in the field.⁴

³ Bordeaux mixture and bluestone-lime mixture are identical.

⁴ Bordeaux mixture was first recommended for the control of wildfire in tobacco beds by Chapman and Anderson. Mass. Agr. Expt. Sta. Bull. 203. 1921.

Experiments were made from 1936 to 1939 in Todd and Logan counties to test, under average farm conditions, the effectiveness of Bordeaux treatment of tobacco beds in the control of wildfire and angular leafspot in the beds and of blackfire in the field. A 3-3-50 Bordeaux was applied with a sprinkling can at the rate of 1 quart to the square yard, without removal of the cotton, when the plants were forming the first true leaves and again 10 to 14 days later. The results of these tests, given in table 1, show that Bordeaux mixture almost entirely controlled wildfire and angular leafspot. Of 277 beds receiving Bordeaux, 7 had a trace of wildfire and 4 a trace of angular leafspot. Infections may have been present in these beds when the first application of Bordeaux was made because the plants were larger, in some of the beds, than they should have been for the first treatment. Of 881 untreated beds observed during the period of the test, 313, or 35 percent, were infected with wildfire and 277, or 31 percent, were infected with angular leafspot.

Table 1. Wildfire and angular leafspot in tobacco beds treated twice with Bordeaux, and in untreated beds. Western Kentucky, 1936 to 1939.

Kind of tobacco and crop year		Percent of beds with				Number of beds examined	
		Wildfire		Angular leafspot		Treated	Not treated
		Treated	Not treated	Treated	Not treated		
Dark Fire-cured	1936	5.7*	15.8	1.9*	6.6	53	76
	1937	0.0	35.2	0.0	5.6	58	142
	1938	0.0	52.7	0.0	35.5	66	93
	1939	0.0	32.4	0.0	22.5	7	71
	Average	1.4	34.0	0.5	17.6	184	382
One Sucker	1936	33.3*	75.0	16.7*	6.3	6	16
	1937	0.0	35.9	0.0	18.8	17	64
	1938	0.0	30.0	0.0	18.9	15	53
	1939	0.0	34.7	0.0	14.3	2	49
	Average	8.4	43.9	4.2	14.6	40	182
White Burley	1936	0.0	8.4	0.0	41.7	9	12
	1937	12.5	45.1	12.5	68.2†	16	66
	1938	0.0	51.3	0.0	90.0†	24	80
	1939	0.0	24.6	0.0	39.6	4	159
	Average	3.1	32.4	3.1	59.9	53	317

*Plants received first treatment later than other beds this year.

† Some beds had both wildfire and angular leafspot.

The effectiveness of Bordeaux in preventing wildfire and angular leafspot in tobacco beds is illustrated by the following. On one

farm each of 9 tobacco beds received two treatments of Bordeaux. On one bed, a narrow strip the length of the bed, outside the frame, was not covered with cotton. When the first application of Bordeaux was made, none was applied to this strip because no plants were up and it was assumed that the area had not been seeded. Records do not show whether this uncovered strip received the second application of Bordeaux. Twenty-seven days after the first treatment with Bordeaux, when the plants were almost large enough to set, all of the plants outside the frame and cotton, which failed to receive Bordeaux, were infected with wildfire or angular leafspot, the former greatly predominating. The balance of this bed and the other 8 were free of wildfire and angular leafspot. In another instance the supply of Bordeaux was exhausted after a grower had treated all of his beds except half of one. The untreated half of this Burley bed was affected with angular leaf spot but the treated half and 5 other treated beds were free of the disease.

Bordeaux seems to be applied entirely as a soil treatment. The requisite amount of the mixture can be applied with less cost and labor with a sprinkling can than with a pressure sprayer. The use of a sprinkling can for this purpose has been found to be a more effective method than the use of a spray outfit because, by the latter method, there is a tendency to apply less than the recommended amount.

Extensive observations on the use of ready-mixed Bordeaux and copper-lime dusts, applied as dusts, indicate that they give poor control of wildfire and angular leafspot; hence they are not recommended for use.

BORDEAUX TREATMENT OF TOBACCO BEDS HELPS IN THE CONTROL OF BLACKFIRE

Tobacco fields, set with plants from Bordeaux-treated beds, were observed from the time of setting until harvest, during each of the 4 years the tests were conducted. Tobacco fields set with plants from untreated beds, located near those set from treated beds, were also observed. The results of these observations, given in table 2, show that in 1936, '37 and '39 fields set with plants from Bordeaux-treated beds were little injured by blackfire whereas the loss from blackfire in some fields set with plants from untreated beds, was

often high enough to make the crop unprofitable. Despite almost continuous rains during the latter critical half of the growing season in 1938, some profitable crops set with plants from Bordeaux-

Table 2. Losses from blackfire in tobacco fields set from Bordeaux-treated and untreated beds Western Kentucky, 1936 to 1939.

Kind of tobacco	Percent of loss	1936		1937		1938		1939		Total fields	
		Treated	Not treated	Treated	Not treated	Treated	Not treated	Treated	Not treated	Treated	Not treated
Dark fire-cured	0	19	7	27	5	1		51	10	98	22
	1	2	4	9	5	4			2	15	11
	5		5		8	3			2	3	15
	10		2		5	3	3		4	3	14
	15		2	1	3	3			1	4	6
	20				3	5			2	5	5
	25				5	6			2	6	7
	30					3				3	
	40					3	2			3	2
	50					6	14			6	14
	60					3	4			3	4
	70					3	3			3	3
	80					2	1			2	1
	90					1				1	
	100						5				5
Average		0.1	4.0	0.7	10.0	33.0	57	0.0	7.0		
One sucker	0	7	2	10	5			26	8	43	15
	1			2	9			1	5	3	14
	5		5		2	1			2	1	9
	10				14	1			9	1	23
	15		1		5	1			4	1	10
	20		1		7				5		13
	25				8	3			1	3	9
	30				1	3				3	1
	40					3				3	
	50				3	2	4		1	2	8
	60						4				4
	70					1	1			1	1
	80					2					
	90					2	4			2	4
	100						3			2	3
Average		0.0	7.0	0.2	14.0	45.0	73.0	0.1	8.0		
White Burley	0	6		9	2	1	1	24	6	40	9
	1			3	12	4		1	2	8	14
	5				2	2	1		1	2	4
	10				5	1				1	5
	15				1						1
	20					3				3	
	25				1		1				2
Average		0.0	0.0	0.2	5.0	7.0	10.0	0.0	1.0		

treated beds were cut, whereas few fields set with plants from untreated beds could be cut with profit. The average loss in 1938 in fields of the dark types of tobacco set from treated beds was 39 percent and the average loss in fields from untreated beds was 65 percent. In this area many fields set with plants from untreated beds were disked under in mid-July, whereas most fields set with plants from treated beds were still not greatly injured in mid-August. In 1938 tobacco matured early and many crops could have been harvested by the third week in August if rains had not continued. These results indicate that in seasons of average rainfall or even in seasons when rainfall is slightly above normal, as in 1937, Bordeaux treatment can be expected to prevent great damage from blackfire.

USE OF PLANTS AFFECTED WITH WILDFIRE OR ANGULAR LEAFSPOT IS INADVISABLE

The importance of preventing plant-bed infection with wildfire or angular leafspot, in the control of blackfire late in the season, is further illustrated in a study made of losses in fields set from beds known to be affected with wildfire or angular leafspot (table 3). Tobacco plants in fields set from beds affected with either wildfire or angular leafspot usually show infection soon after setting. In table 4 are given the percentages of infection, 2 to 6 weeks after setting, in fields set with tobacco plants from beds affected with wildfire or angular leafspot. These results are for 1939 only, but they are similar to those of other years. Percentages of plants infected are sometimes low for some time after setting but usually there is a gradual increase in size and number of spots per plant. This increase may be very rapid if rains are frequent or if dew is heavy. Just a few days after heavy rains, fields that had a small percentage of plants affected with wildfire or angular leafspot sometimes show 100 percent infection. Sometimes an occasional wildfire or angular leafspot affected plant appears in tobacco fields from treated beds about mid-season indicating that there is an unknown source of field infection in addition to that carried to the field on diseased plants; but it is believed that these results indicate that infection in the bed is an important source and can be eliminated by Bordeaux treatment.

Table 3. Loss from blackfire in tobacco fields set from beds affected with wildfire and angular leafspot. The number of beds is the same as the number of fields.

Disease in the beds	1936		1937		1938		1939	
	Loss percent	Number of fields	Loss percent	Number of fields	Loss percent	Number of fields	Loss percent	Number of fields
Wildfire only	5	2	10	4	5	1	1	14
	15	2	15	2	15	3	5	4
	20	2	20	3	20	1	10	4
			25	1	30	1	15	2
					50	1	20	3
					60	2	25	1
					100	4	50	1
		6		10		13		29
Wildfire and angular leafspot			none	1			1	6
			5	1			5	2
			10	1			10	2
			15	1			15	2
			25	1			20	1
				5				13
Angular leafspot only			none	3			10	3
			5	3			20	1
			10	1			25	1
			15	1				
			25	1				
				9				5
Total number of fields		6		24		13		47

"BORROWING" PLANTS IS NOT ADVISABLE

Sometimes a grower may set part of his crop with plants obtained from a neighbor, usually after the neighbor has finished setting and has used most of the desirable plants. This practice is undesirable because not only wildfire and angular leafspot may be introduced

Table 4. Wildfire and angular leafspot in tobacco fields 2 to 6 weeks after setting with plants from affected beds.

Percent of diseased plants	Number of fields with	
	Wildfire	Angular leafspot
Trace to 5	13	10
6 to 10	4	2
11 to 15	5	2
16 to 25	7	2
26 to 50	6	1
51 to 100	5	2
	40	19

into the field from the bed but very often a planting from a bed which has been pulled over once has a high percentage of mosaic, if the workmen who pulled plants for the first setting, used home-cured tobacco. Also several cases are known of the introduction of black root-rot to the field from the bed. As regards the bacterial leafspots the practice is especially undesirable if a grower who has treated his beds with Bordeaux, gets plants from an untreated bed and sets them in a field with plants from treated beds.

For example, a grower treated all his beds with Bordeaux except a small isolated bed of a test variety. Two rows of plants from the latter bed were set in a field planted from a treated bed. In mid-season 30 percent of the plants from the untreated bed had blackfire. No blackfire developed in the balance of the field.

In a Burley field rows 1 to 35 and $\frac{3}{4}$ of rows 36, 37 and 38 were set with tobacco plants from a neighbor's untreated bed. Four weeks after setting wildfire was present on all the plants in these rows. The remainder of the planting was set with plants from a Bordeaux-treated bed. Four weeks after setting there was a trace of angular leafspot but no wildfire in these rows. At cutting time, there was a loss of 15 percent in the part of the field set with plants from untreated beds and none or only a trace in the part set with plants from the treated bed.

In 1937 a grower set 41 rows of one-sucker tobacco from his own beds. Forty-eight rows in the same field were set with plants obtained from a neighbor. At mid-season there was a small amount of angular leafspot in the first 41 rows and no wildfire, while in the next 48 rows the percentage of wildfire was high. At cutting time there was a loss of 10 percent in the 41 rows and 25 percent loss in the 48 rows. In the latter there were areas where many plants were not cut because of blackfire damage.

A grower who treated all his beds of dark fire-cured tobacco with Bordeaux had half the plants in the beds destroyed by cutworms; consequently he set half his crop with plants from a neighbor's untreated bed which was infected with angular leafspot. Tobacco grown from his own plants was free of blackfire at cutting time, while blackfire caused a loss of 10 percent in the half of the field set with plants from the untreated bed.

Sometimes growers who have not treated their own beds profit

by getting plants from Bordeaux-treated beds. In the epiphytotic of 1938, a grower who treated his beds, gave plants to two growers neither of whom had treated. Both these growers, whose farms were in different areas, cut good crops from the parts of their fields set with treated plants but none was cut from areas set with plants from untreated beds.

BLACKFIRE AND SOIL FERTILITY

For a number of years the writers have believed that blackfire is more likely to be destructive on soils of low fertility. In a breeding plot on the Station farm at Lexington, where fertility is high and where manure is applied annually, blackfire has not occurred. The writers have been unable to induce blackfire in tobacco in this fertile plot or in other fertile plots on the Station farm, by inoculating plants with pure cultures of *Bact. tabacum* and *Bact. angulatum*, the inoculations resulting only in wildfire and angular leafspot on rapidly growing untopped plants and usually no spots whatever on topped dark tobacco. In 1935, in a field on the Station farm, blackfire was destructive in certain areas. These were sub-soil areas, low in fertility, having at one time been knolls which were leveled to improve the appearance of the field. Blackfire identical with that occurring naturally was induced in Burley tobacco in this infertile area by inoculations with pure cultures of *Bact. angulatum*. Pure-culture inoculations of tobacco on fertile areas of the same field caused only angular leafspot. Blackfire is induced without difficulty if weather conditions are favorable by inoculating dark tobacco with *Bact. angulatum* and *Bact. tabacum*, on the infertile tobacco soils of western Kentucky.

It is believed that a system of soil management which builds up large reserves of available plant food is imperative in aiding in control of blackfire for the following reasons: (1) blackfire rarely occurs on fertile soils; (2) the disease often occurs in epidemic form on soils of low fertility; (3) blackfire can be induced without difficulty in tobacco on infertile soil by inoculations with pure cultures of *Bact. tabacum* and *Bact. angulatum*.

MANURE HELPS TO PREVENT BLACKFIRE LOSSES

Several years ago the junior author observed a field of dark tobacco in Christian county that was entirely destroyed by blackfire

except for a semi-circular area where well-rotted manure had been spread. In this small area the tobacco appeared to be of an entirely different variety as the leaves were broad and smooth and showed no spotting whatever. The leaves of plants in the remainder of the field were curled downward, rough, and showed definite evidence of potash starvation. Similar observations have been made by growers. In table 5 are observations, taken over a 5-year period, on the effect of manure in the prevention of injury from blackfire. Fields on the same farm, which received manure and commercial fertilizers, are compared with those which received commercial fertilizers only. Even in wet seasons, as 1935, 1937, and 1938, damage from blackfire was much reduced and sometimes entirely prevented by the use of stable manure. In 1938 several growers reported that they produced marketable tobacco on manured areas of fields while that on unmanured areas of the same field was a total loss. It appears that to be most effective, manure should be well rotted or at least relatively free of undecomposed straw. In 1936, in a field where strawy manure was used on one-third of it, there was a loss of 25 percent from blackfire and on the balance of the field, where rotted manure was used, the loss was negligible (table 5).

Table 5. Effect of manure in preventing blackfire in dark tobacco. Observations in fields in Western Kentucky. D F stands for Dark Fired; O S for One Sucker.

Year, farm number and tobacco kind of	Percent of blackfire injury		Remarks
	Both manure applied and fertilizer	Only commercial applied fertilizer	
1935			
1 D F	trace		
1 D F		great	Had to cut green
1 D F		great	Had to cut green
2 D F	trace		Originally poorest field on the farm.
2 D F		25	Had to cut green
2 D F		25	Had to cut green
3 D F	trace		
3 D F		great	Had to cut green
4 O S	none		
4 O S		40	Some left in field
5 O S	none		Old feeding lot
5 O S		10	

Table 5. (Continued.)

Year, farm number and tobacco kind of	Percent of blackfire injury		Remarks
	Both manure applied and fertilizer	Only commercial applied fertilizer	
1936			
6 OS	trace		Well-rotted manure
6 OS	25		Strawy manure
1937			
7 OS	trace		
7 OS		high	Had to cut green. Potash hunger and frenching present
8 OS	none		
8 OS		50	Much of crop not worth cutting
9 DF	10		
9 DF		25	
10 DF	2		
10 DF		20	
10 DF		30	Had to cut some green
11 OS	none		
11 OS		10	
1938			
12 OS	25		Only tobacco on the farm worth cutting
12 OS		70	Little worth cutting
13 DF	5		Stood until mature
13 DF		60	Very little cut
14 DF	10		Hog lot. Stood until mature
14 DF		40	Had to cut green
14 DF	20		Barn lot. Stood 2 weeks long- er than the fertilized to- bacco
15 DF	trace		
15 DF		50	Had to cut green
16 OS	60		
1939			
17 OS	3		Stood until mature
17 OS		20	Had to cut green
18 OS	none		
18 OS		10	
19 DF	trace		Manure 3 sides of field only. Contrast between manured and not manured parts great.
19 DF		20	
20 OS	5		
20 OS		20	Cut some green
21 OS	2		
21 OS		25	Had to cut green
22 OS	trace		
22 OS		15	
23 OS	10		
23 OS		50	Had to cut 2 weeks before the above
23 OS	trace		
23 OS		15	Had to cut some green

SOILS OF THE DARK-TOBACCO AREA OFTEN ARE LOW IN FERTILITY

In the dark-tobacco districts of Kentucky the rotations used for tobacco cause a heavy draft on plant food. The common rotation is wheat, lespedeza 2 to 5 years or longer, and tobacco. Small amounts of fertilizer are sometimes used on wheat but more often none is used. The grain is threshed and the straw is rarely returned. A crop of lespedeza hay is cut in the fall following wheat harvest and hay or seed crops are harvested as long as the field is not too weedy. The lespedeza is then pastured for one to a few years. The lespedeza straw from a seed crop is rarely returned to the field from which it came. In addition to the nutrients removed in the wheat and lespedeza crops, a great deal of plant food is lost by leaching because lespedeza fields are almost bare in winter. It is not only nitrogen that is lost by leaching but also minerals such as potassium and calcium because all of the nitrogen which leaches is combined with some mineral. When the lespedeza sod is prepared for tobacco, 100 to 200 pounds of a low analysis fertilizer is usually used in the hill and manure is sometimes applied on eroded upland. The small amounts of fertilizer used for tobacco, and sometimes for wheat, are insufficient to compensate for that removed by cropping and leaching. Tobacco is also grown in continuous culture with a crimson-clover crop turned under at the full-bloom stage in the spring, between tobacco crops. This system might be expected to maintain the nitrogen supply and prevent loss of plant food by leaching but, as in the other rotation, insufficient fertilizer is used for tobacco to compensate for that removed so that the soluble mineral plant food is soon reduced to a low level. Tests of soils collected, soon after tobacco was set and rarely later than mid-season, from tobacco fields in western Kentucky, from 1937 to 1939 show that most of them are low in soluble phosphorus and potassium. Of 268 fields tested 227, or 84 percent, were too low in either phosphorus or potassium or both and only 41 fields, or 16 percent, possibly had sufficient of these elements for tobacco (table 6). This is shown graphically in figure 5. Small amounts of soluble phosphorus and potassium may be indicative of small amounts of other essential plant food elements, especially nitrogen.

The increasing use of lime and phosphate, with the consequent increase in crop yields, rapidly depletes other essential elements as potash and probably the so-called trace elements, making it more and more necessary that attention be given to supplying a well-balanced fertilizer for tobacco.

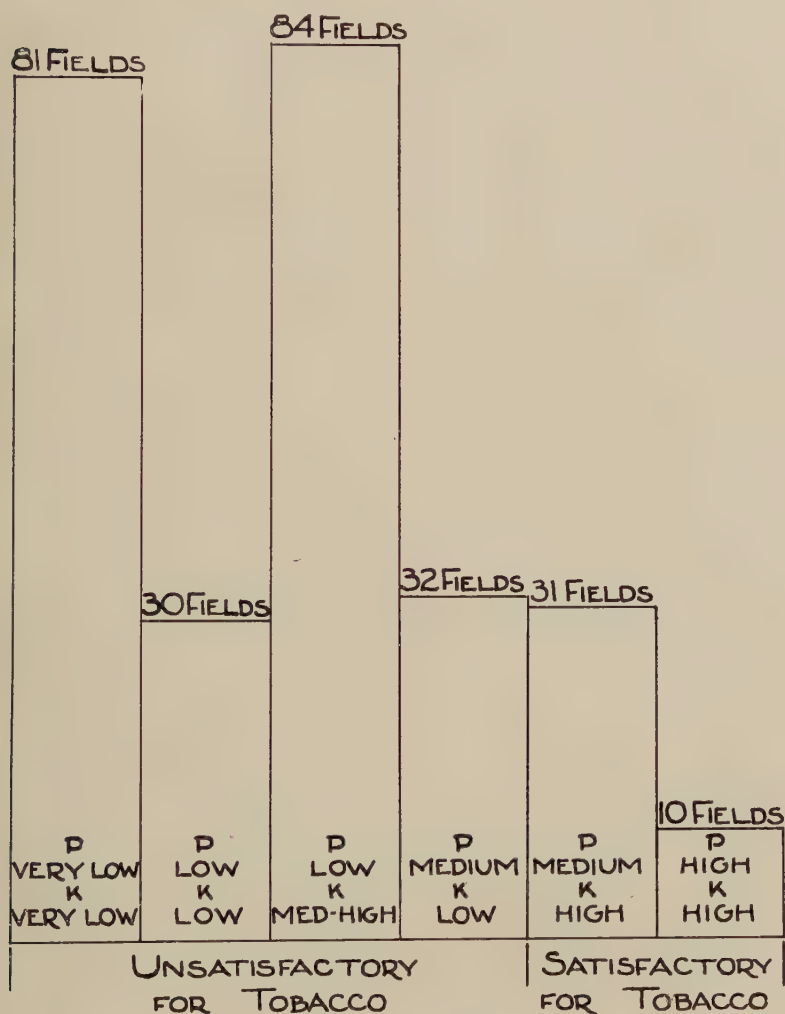


Figure 5. Soluble phosphorus (P) and potassium (K) in the soil of tobacco fields in Western Kentucky, 1937, 1938, and 1939.

Table 6. Soluble phosphorus and potassium in tobacco fields. Western Kentucky, 1937-8-9. P = phosphorus, Hi-Lo method, K = potassium, Purdue method.

Year	P very low K very low Number of fields.	P low K low Number of fields.	P low K medium to high Number of fields.	P medium K low Number of fields.	P medium K high Number of fields.	P high K high Number of fields.
1937	9	7	15	6	5	0
1938	40	16	34	16	8	3
1939	32	7	35	10	18	7
Totals	81	30	84	32	31	10

GOOD SOIL MANAGEMENT IS NECESSARY FOR PROFITABLE PRODUCTION OF DARK TOBACCO

Recommendations for soil management and fertilization for tobacco are given in Kentucky Experiment Station Bulletin No. 379, a summary of which follows.

Select the land best adapted to tobacco even if it necessitates some rearrangement of fields or more or less "patch" farming. It might be practical for many growers to select certain lots on which tobacco will be the main if not the only revenue crop. Other crops on these lots should be considered as steps in preparing land for tobacco. Tobacco land should have good underdrainage which is indicated by well-granulated reddish, brownish-red or bright yellow subsoil. Poor drainage is indicated by a light-colored, compact subsoil and the presence of dark-colored concretions (buckshot).

A tobacco soil should be fertile enough to yield 1,000 pounds of tobacco an acre in a good season without fertilization other than that used in improving the soil. A field with a good grass and legume sod, not heavily pastured, is desirable. The longer in sod, the better. Poor quality tobacco and low yields usually follow lespedeza, alfalfa, and other legumes if they are cut year after year for hay. Lands intended for tobacco should receive 300 to 400 pounds of 20-percent superphosphate broadcast ahead of seeding the grass and legume mixture. If the soil has not been limed, only sufficient lime should be added for the legume. On many soils a ton is sufficient. The land should then be seeded to a good pasture mixture such as 3 pounds of redtop, 8-10 pounds of orchard grass, 3-4 pounds of Kentucky bluegrass, 3-4 pounds of Canada bluegrass,

5 pounds of native red clover, not over 5 pounds of Korean lespedeza, and 2 pounds of white clover per acre. It is desirable that the grass-legume mixture be pastured rather than cut for hay and pastured lightly or not at all the year preceding tobacco.

The use of 6-8 tons of manure with a high-grade fertilizer will increase the yield and quality of dark tobacco. A 4-10-6 fertilizer or a similar analysis is satisfactory for dark tobacco. The amount to use varies with the fertility of the soil and the amount of manure used. On more fertile and heavily manured soils not less than 300 pounds, and on the less fertile soils 600 to 700 pounds or more should be profitable. On phosphate-deficient soils (most western Kentucky soils) that have not been liberally fertilized with phosphate in producing the sod for tobacco, 300-400 pounds of 20-percent superphosphate will probably be profitable on the tobacco and will be of great benefit to the wheat and grass that follow.

A study of the soil management practices used at the Mayfield



Figure 6. Dark fire-cured tobacco topped high. On soil of satisfactory fertility dark fire-cured tobacco may be topped at 16-20 leaves. Yields of 1000 pounds per acre of the leaf grades are not unusual.

and Greenville soil fields and at the Princeton substation will be of benefit to dark-tobacco growers of western Kentucky.

DISCUSSION

Bordeaux (Bluestone-lime) treatment should always be used because it is easy to apply and one is almost certain to have wildfire and angular leafspot free plants for setting. The tests also indicate that, in most years, Bordeaux treatment of tobacco beds prevents injury from blackfire in the field late in the season or greatly reduces it.

It is common observation that early-maturing tobacco plants topped low (10-12 leaves) are more susceptible to blackfire injury than those topped high (16-20 leaves). The contention of some dark-tobacco growers that dark tobacco topped higher than 12 leaves will not cure with sufficient body, is probably true for most dark-tobacco soils as they are now managed. Most of these soils probably would not support plants of greater size without additional nutrients. With proper soil management, heavy manuring and fertilization, the height of topping can be increased over that now commonly used, with resultant higher yields and freedom from blackfire. In certain areas in western Kentucky, growers are producing, by the liberal use of manure and commercial fertilizers on grass sods, high yields and high quality of dark fire-cured tobacco topped at 16-20 leaves. Yields of 1,000 pounds of the leaf grades are not unusual (figure 6). Where dark tobacco is topped at 10-12 leaves, in most of the dark tobacco district, a total yield of 1,000 pounds per acre of all grades is considered satisfactory (figure 7). In the wet year of 1938, one of the growers who fertilized heavily and topped high, harvested a crop free of blackfire while neighbors who topped at 10 leaves on soils low in fertility cut little or no tobacco because of blackfire.

Heavy fertilization, manuring and proper soil management not only produce tobacco which can be topped higher and give heavier yields of the desirable grades but definitely increase the resistance of the tobacco plant to the leafspot diseases after topping. The soil should contain liberal quantities of available phosphorus and nitrogen compounds but in addition should contain liberal quantities of potash. An actual or partial deficiency of potash has, for a long

time, been recognized as one of the causes of susceptibility to destructive leaf diseases. The survey of tobacco soils reported in this bulletin proves that very few fields in which tobacco is grown contain sufficient available nutrients to produce a satisfactory crop of tobacco. In addition to Bordeaux mixture the tobacco grower



Figure 7. Dark fire-cured tobacco topped low. On most dark-tobacco soils dark fire-cured tobacco is topped at 10-12 leaves. A yield of 1000 pounds per acre of all grades is considered satisfactory.

must rely on good soil management if he expects to produce dark tobacco free from leafspot injury.

SUMMARY

Blackfire, a late-season disease of tobacco, caused by either *Bacterium tabacum* or *Bact. angulatum* together with wet weather and unsatisfactory soil conditions, yearly causes some loss of dark tobaccos and in seasons of heavy rainfall, as in 1938, destroys many crops.

Blackfire is characterized by the presence on the leaves of to-

bacco, usually after topping and suckering, of few to many dead, brown, zonate spots of various shapes, $\frac{1}{4}$ to several inches in diameter.

Infections with *Bact. tabacum* and *Bact. angularum* on young, actively growing plants are easily distinguishable. The former, known as wildfire, are usually circular, dead areas surrounded by a broad lemon-yellow halo. *Bact. angularum* spots, known as angular leafspots, are usually angular, dead, brown areas with no haloes. Wildfire or angular leafspot often destroy many young plants in the bed. Half-grown or larger seedlings are rarely killed but their growth may be retarded.

In extensive tests in western Kentucky from 1936 to 1939, a 3-3-50 Bordeaux mixture applied to tobacco beds with a sprinkling can without removal of the cotton, when the first true leaves appeared and again 10-14 days later, usually completely prevented wildfire and angular leafspot in the bed. Blackfire was either entirely prevented or greatly delayed in the fields set from treated beds. In the few treated beds where these diseases appeared fewer than twelve affected plants per bed were found.

Damage from blackfire to dark tobacco types, in fields set from treated beds, was slight in 1936, 7 and 9. During these years the damage in fields set from untreated beds was sometimes as great as 50 percent. In 1938, when rainfall was excessive thruout the growing season, the average loss in fields set from treated beds was 39 percent and in fields set from untreated beds 65 percent.

Wildfire or angular leafspot develop in the field soon after setting if the diseases were present in the bed. There is a gradual increase in size and number of spots and if rains are frequent or heavy, damage from blackfire develops rapidly in such fields. In the rainy year of 1938 many fields that had wildfire or angular leafspot soon after setting were destroyed with blackfire by mid-July, whereas those from treated beds were still little injured by mid-August.

Blackfire causes greater damage to tobacco on soils of low fertility. The disease is rarely of consequence on the highly fertile soils at Lexington nor at the Princeton substation and Greenville and Mayfield soil fields where the soils are being improved by a good system of soil management. In western Kentucky, where

blackfire damage is high, tests show that more than 80 percent of the fields are too low in phosphorus and potassium for satisfactory growth of tobacco. This condition, especially low potassium, increases the susceptibility of plants to injury.

By using a rotation with 2 to several years of a grass-legume mixture, not too heavily pastured, and generous applications of manure and fertilizers, dark tobacco can be topped at 16-20 instead of 10-12 leaves, and may be expected to give increased yields of high-quality tobacco relatively free of blackfire damage.

Casual observations for a number of years and more detailed observation from 1935 to 1939 indicate that applications of well rotted stable manure often prevent damage from blackfire.

A combination of Bordeaux treatment of plant beds and the best soil practices must be followed if high yields of relatively disease free, high-quality tobacco are to be obtained.

Kentucky Agricultural Experiment Station

University of Kentucky

THE SIGNIFICANCE OF BIOLOGICAL TYPES OF SALMONELLA TYPHI-MURIUM (*Salmonella aertrycke*)

BULLETIN NO. 400



Lexington, Ky.

March, 1940

THE SIGNIFICANCE OF BIOLOGICAL TYPES OF
SALMONELLA TYPHI-MURIUM

(*Salmonella aertrycke*)

By P. R. EDWARDS and D. W. BRUNER

The frequent occurrence of epidemics of *Salmonella* infections has been a continual stimulus to the study of the methods of dissemination of these diseases among both men and animals. The value and importance of epidemiological studies in the field of disease prevention have become increasingly apparent and much effort has been expended to enhance their accuracy. Obviously these studies are dependent upon exact differentiation of bacterial species and where possible the recognition of epidemic types within a single species.

In a survey of paratyphoid infection among domestic animals in the United States the writers studied approximately 700 cultures derived from 350 outbreaks of disease. Altho 30 species of paratyphoid bacilli were involved in the study, a single species, *Salmonella typhi-murium*, comprised more than 50 percent of the cultures studied. When infection due to one of the more rarely occurring species is being investigated, the detection of carriers of that type is rather conclusive evidence that they were connected with that outbreak of disease. Conversely, the extremely wide zoological distribution and frequent occurrence of *S. typhi-murium* often cause confusion in attempts to determine the origin of infection due to this microorganism. The detection of animal carriers of the bacillus on premises where infection has occurred does not irrevocably incriminate these carriers as the vectors of the disease since practically all warm-blooded animals may, and often do, carry the bacilli. It is evident that any method of distinguishing different strains of such an ubiquitous species would be of great value in determining the source of infection. The purpose of the present publication is to present evidence that different types can be distinguished within the species and that they possess epizootic significance.

It has been known for many years that different strains within a given species of the typhoid-paratyphoid group display biochemical irregularities. Jensen (1901) noted that certain cultures of *S. typhi* fermented xylose while other cultures did not. Mandelbaum (1908) made a similar observation in regard to the fermentation of glycerol by *S. typhi*, and Braun and Cahn-Bronner (1922) found discrepancies in the growth of typhoid strains in a synthetic medium containing ammonium salts. It remained for Kristensen and Henricksen (1926) to demonstrate that these individual differences in typhoid cultures could be used to advantage in epidemiological studies. These workers examined a large number of cultures of *S. typhi* and found that their action on xylose was epidemically significant. All the strains from a given epidemic were identical in their behavior toward this substance. The species was divided into two types, type I which fermented xylose and type II which did not. While the majority of cultures found in Denmark belonged to type I, several epidemics were due to type II. On the Faro Islands, the population of which constitutes a rather isolated community, the rarer type II was found exclusively. Schiff (1929) examined strains of *S. typhi* that originated in Germany and confirmed the observations of Kristensen and Henricksen. In most of the provinces of Germany, type II made up less than 10 percent of the cultures studied but comprised 48 percent of those isolated in Wuertemberg.

Kristensen and Bojlen (1929) extended the study of epidemic types to *S. paratyphi B*. They examined 1019 cultures of this bacillus which were isolated in Denmark. It was found that some strains fermented rhamnose quite rapidly while others attacked the sugar slowly. Likewise certain cultures caused a rapid production of acid in inositol broth while others acidified the medium only after prolonged incubation. The strains were divided into 5 types according to their rapidity of action on these two substances, and their reaction in the rhamnose test of Bitter, Weigmann and Habs (1926). All the cultures from a single epidemic belonged to the same type. It was further demonstrated that the types were constant and did not change when the bacilli were cultivated in the laboratory for long periods. While in some instances strains which

fermented rhamnose slowly could be transformed into rapid fermenters by cultivation on rhamnose agar and selection of colonies, this change never occurred when the organisms were cultivated on a medium which did not contain rhamnose. The uniform results obtained by Kristensen and Bojlen in the study of such a large number of cultures were remarkable and demonstrated beyond question the value of the division of a bacterial species into epidemic types. The work of Kristensen and Bojlen was confirmed by Vogelsang (1934) and by Warren and Iredale (1934) who further demonstrated that the property of anaerogenesis in *S. paratyphi B* could be used to divide the species into epidemically significant types.

A number of methods have been advocated to distinguish different strains of *S. typhi-murium*. These methods, in part biochemical and in part serological, were designed for two purposes; first, to distinguish strains from different outbreaks of the infection and, second, to correlate certain varieties with specific animal hosts. Moltke (1926) studied 13 cultures of *S. typhi-murium* from 6 outbreaks of food poisoning. He found that 8 strains derived from 3 outbreaks failed to ferment inositol within the incubation period of 14 days, while the remainder fermented the substance with the production of acid and gas, within 24 hours. All the strains from any one outbreak were the same in their behavior toward inositol and Moltke suggested that this observation might be of value in studying the epidemiology of the infection. Edwards and Rettger (1927) noted that certain cultures of *S. typhi-murium* produced acid from xylose quite slowly, while others attacked the sugar vigorously. The full significance of this observation was not realized at that time. Later Edwards (1936) reported on 47 cultures of the bacillus derived from 7 outbreaks of disease in ducks, canaries, horses, guinea pigs and mice. Thru the action of these bacteria on maltose, xylose and rhamnose in the peptone-salt medium of Bitter, Weigmann and Habs (1926), 4 epizootically significant types were obtained. Following their work on *S. paratyphi B*, Kristensen and Bojlen (1936) examined 253 cultures of *S. typhi-murium*. These strains, which were derived from 167 patients, were divided into 8 types by the rapidity of their action on dulci-

tol, rhamnose, inositol and *d*-sodium tartrate. On the whole, epidemically related cultures belonged to the same type and the writers did not agree with the conclusion of Habs (1934) that inositol fermentation was worthless for the detection of related strains.

Hohn and Herrmann (1936, 1936a, 1937, 1939), Herrmann (1936) and Hohn (1937) investigated the biochemical activity of a number of species of the typhoid-paratyphoid group. In these studies they employed an agar medium containing $\text{NaNH}_4\text{HPO}_4$ as the sole source of nitrogen. To this basic medium were added glucose, arabinose, dulcitol, rhamnose and sodium citrate as sources of carbon. They tested the ability of the various strains to utilize each of these sources of carbon in the synthetic medium. In addition they examined the fermentative action of the organisms on glucose, arabinose, dulcitol and rhamnose when the fermentable substances were incorporated in a medium composed of a tryptic digest of beef testes. From the results of these tests they evolved the theory that species which failed to develop on the synthetic agar and did not utilize each carbohydrate in the tryptic digest medium were more restricted in their host relationships than were species which grew well in the mediums and produced acid and gas from the fermentable substances. While the general scope of this work is not pertinent to the present discussion, their results with *S. typhimurium* demand attention. They divided this species into four cultural types and correlated these types with host origin. The types were as follows:

1. The "full" type which utilized all sources of carbon in sodium ammonium phosphate agar and produced acid and gas from all the fermentable substances in testicular digest broth. This type was found in all animal species and possessed no host specificity.
2. The "rhamnose negative" type which failed to utilize rhamnose and dulcitol in sodium ammonium phosphate agar and did not ferment rhamnose in testicular digest broth. This type was found among cultures from ducks and from duck eggs.
3. A type isolated from guinea pigs which resembled the "rhamnose negative" type except that it utilized dulcitol in sodium ammonium phosphate agar.

4. The "ammonia weak" type which failed to utilize any of the sources of carbon in sodium ammonium phosphate agar or which utilized only glucose and sodium citrate in this medium and which produced acid and gas from all the substances tested in testicular digest broth. This type was found only in pigeons and pigeon eggs.

Using the methods outlined above, Hohn and Herrmann concluded that in many cases it was possible to determine the source of *S. typhi-murium* infection in man by the study of the biochemical characteristics of the bacilli responsible for the epidemics. They cited a number of instances in which epidemics due to the "rhamnose negative" type were incited by the consumption of raw duck eggs. The "ammonia weak" type was found in one epidemic in which the 20 persons affected had eaten a dessert prepared from pigeon eggs. Similar bacteria were isolated from the infected individuals and from the dessert.

Lerche (1937) tested 372 cultures of *S. typhi-murium* according to the methods recommended by Hohn and Herrmann. These strains were obtained from a variety of animal species on a number of farms. Included in the study were cultures isolated on post-mortem examination, in meat inspection, and thru systematic examination of feces of animals on premises known to harbor the infection. From this work Lerche concluded that it was not possible to determine the host origin of strains by their biochemical properties and further that epizootically significant types could not be distinguished by their action on fermentable substances. He found the "rhamnose negative" type and "ammonia weak" type of Hohn and Herrmann in all the animal species studied. Lerche (1939) reported the results of a study of 839 cultures of *S. typhi-murium* derived from man and the lower animals. As in his earlier publications, this worker concluded that little relationship existed between the host origin and the different biochemical types of the bacillus. He found that the "rhamnose negative" type composed only 12.2 percent of the cultures from ducks and only 42 percent of his strains from pigeons were "ammonia weak." The "rhamnose negative" type and the "ammonia weak" type were

found in the majority of animal species from which *S. typhi-murium* was isolated.

The possibility of differentiating epidemic types of *S. typhi-murium* by serological methods also has been considered. Kauffmann (1934) noted that certain cultures of *S. paratyphi B* and *S. typhi-murium* lacked the antigen V found in the somatic complex of typical strains of these two species. He suggested that the lack of antigen V could be used to distinguish between strains from different sources. Edwards (1935, 1936a) observed that 13 cultures of *S. typhi-murium* isolated from pigeons all lacked antigen V, while 37 strains derived from mice, guinea pigs, canaries, ducks and horses all possessed this antigen. Hohn and Herrmann (1937) also described the lack of antigen V in cultures from pigeons but attributed no significance to its absence since the same serological type appeared in other animals. Christensen (1937) found that certain cultures of *S. typhi-murium* contained antigen I of the Kauffmann-White classification while others did not. His observations led him to believe that the presence or absence of this antigen was of value in distinguishing epidemic types. Lerche (1939) examined the somatic antigens of 117 strains of *S. typhi-murium*. He found IV variants among cultures isolated from horses, cattle, swine, pigeons, geese, pheasants and wild birds. Only in pigeons did this type predominate; in these birds 78 percent of the bacilli were IV variants. They also composed 40 percent of 15 cultures from horses. Lerche doubts the epizootic significance of IV variants since both these forms and bacilli containing antigen V were isolated from pigeons in the same flock.

From the foregoing review it is evident that the problem of distinguishing epidemic types in *S. typhi-murium* has attracted much attention and that no general agreement has been reached by the workers who have attempted its solution. Since the writers had in their possession 391 cultures of the bacillus derived from 180 outbreaks in a variety of domestic animals it was decided to attempt their separation into epizootic types. In this work attention was given both to the differentiation of strains from outbreaks of the infection and the correlation of certain types with a specific animal host. In the beginning the action of representa-

tive strains on a large number of fermentable substances was tested. Preliminary work indicated that the best results could be obtained by combining the methods of Hohn and Herrmann (1936) with the reactions obtained in the peptone-salt medium of Bitter, Weigmann and Habs to which had been added maltose, xylose and rhamnose. In addition a careful examination of the somatic antigens of each strain was made. In this way the species was divided into a number of types which seem to be significant.

Before presenting the results of the study it is necessary to define accurately the species under investigation. During the forty years that have elapsed since Loeffler originally isolated the bacillus it has been designated by a variety of terms. Since this varied terminology is quite confusing to persons who have not studied the genus *Salmonella* intensively, it seems desirable to list the names applied to the bacillus. The following terms are considered as synonyms for this species:

Bacterium typhi murium. Loeffler, Zbt.f.Bakt., 1892, 11, 129.

Bacillus psittacosis Nocard, Conseil d. Hyg. Publique et Salubrite du Dept. du Seine, Seance, March 24, 1893.

Bacillus of Fluegge — Kaensche }
Kaensche's *Bacillus* } Kaensche. Ztschr. f. Hyg., 1896,
Breslau *Bacillus* } 22, 53.

Bacillus aertrycke De Nobele, Ann. Soc. Med. de Gand, 1898, 72, 281.

Bacillus pestis-caviae Wherry, Jour. Inf. Dis., 1908, 5, 519.

Bacillus cholerae-caviae Wherry, U. S. Public Health Rpts., Nov. 1908.

Bacterium psittacosis Le Blaye and Guggenheim, Manuel Pratique de Diagnostic Bacteriologique, Viget Freres, 1914.

Salmonella typhimurium Castellani and Chalmers, Manual of Trop. Med. 1919, 939.

Salmonella psittacosis Castellani and Chalmers, Manual of Trop. Med. 1919, 939.

Salmonella aertrycke Castellani and Chalmers, Manual of Trop. Med. 1919, 939.

Bacillus paratyphosus B Mutton type Schuetze, Lancet 1920, i, 93.

Group VII of Hecht-Johansen The Classification of the Typhoid-Paratyphoid Group of Bacilli, Copenhagen, 1923.

Bacterium aertrycke Weldin and Levine, Abstr. Bact., 1923, 7, 13.

Salmonella typhi-murium (Loeffler) Castellani and Chalmers, Salmonella Subcommittee, Jour. Hyg. 1934, 34, 333.

Bacillus paratyphosus B Binns type Schuetze, Lancet, 1920, i, 93.

Salmonella typhi-murium (Loeffler) Castellani and Chalmers var. *binns* (Schuetze), Salmonella Sub-committee, Jour. Hyg., 1934, 34, 333.

Group VI of Hecht-Johansen The Classification of Typhoid-Paratyphoid Group of Bacilli, Copenhagen, 1923.

Salmonella typhi-murium var. *copenhagen* Kauffman, Ztschr. f. Hyg., 1934, 116, 368.

Salmonella aertrycke var. *storrs* Edwards, Jour. Bact., 1935, 30, 465.

In addition to the terms listed above, *S. typhi-murium* embraces the "Mutton" strains of the English workers, *B. enteritidis breslaviense* of the German literature, many "mouse typhoid" bacilli and the majority of "B. paratyphosus B" strains of animal origin.

The organisms classified as *S. typhi-murium* in the present work had the following characteristics. They possessed the morphological, tinctorial and biochemical properties generally attributed to members of the genus *Salmonella*. They were members of Group B of the Kauffmann-White classification (*Salmonella* Subcommittee, 1934) and contained the major heat-stable antigen IV of that group. The cultures were diphasic and possessed the specific antigen i and non-specific antigens 1, 2, 3. All the strains were identified by antigenic analysis before they were included in the study. Special mention should be made of the organisms variously classified as "Binns" type, Group VI of Hecht-Johansen, *S. typhi-murium* var. *copenhagen* and *S. aertrycke* var. *storrs*. While typical strains of *S. typhi-murium* contain both heat-stable antigens IV and V, the above-mentioned types contain only antigen IV. Such cultures commonly are referred to as "IV variants." The "Binns" type, or *S. typhi-murium* var. *binns*, first described by Schuetze (1920) was characterized by White (1925) as a permanently and totally nonspecific counterpart of *S. typhi-murium*. That cultures classified in this category were actually diphasic was demonstrated by Edwards

(1936a) and Bruner and Edwards (1939). They are now regarded merely as predominantly nonspecific strains of *S. typhi-murium* which lack antigen V.

METHODS

In the study of the biochemical and serological properties of the bacilli the methods detailed below were used.

The sodium ammonium phosphate medium recommended by Hohn and Herrmann (1936), was prepared as follows. Finely granulated agar was washed repeatedly with distilled water until the supernatant fluid remained perfectly clear. After each washing the agar was collected on filter paper in a Buchner funnel and freed of as much water as possible by vacuum filtration. Usually six washings, during the last of which the suspension was allowed to set overnight in the refrigerator, were used. The washed agar was employed in the preparation of a medium of the following composition:

Sodium ammonium phosphate	1.5 gm.
Potassium acid phosphate	1.0 gm.
Magnesium sulfate	0.2 gm.
Bromthymol blue (1% alcohol soln.)	10.0 cc.
Agar	20.0 gm.
Distilled water to make 1 liter.	

After heating to dissolve the agar the medium was divided into 5 lots and to these was added 0.2 percent of glucose, arabinose, dulcitol, rhamnose and 0.25 percent sodium citrate, respectively. The pH was 7.0 to 7.2. Each set was tubed in 13x100 mm. culture tubes in 1.5 cc. amounts.

The testicular broth of Hohn and Herrmann (1936) was prepared according to the ensuing procedure. One pound of testes free from epididymis and surrounding connective tissue was divided into longitudinal sections of four to each testis. The sections were placed in 750 cc. of boiling water and cooked for 10 minutes. Then they were removed and put thru a meat mincer. The ground mass was returned to the 750 cc. of broth which previously was cooled to 40 C. and the mixture placed in a flask that allowed adequate room for shaking. Normal NaOH solution was added until the reaction became alkaline to litmus paper and 2 gm. of trypsin and 15 cc. of CHCl_3 were placed in the flask. It

was held at 37 C. for two days at which time the contents were again made alkaline. After the third day of incubation the tryptic action was terminated by the introduction of sufficient N/1 HCl to render the medium acid to litmus paper. To 200 cc. of the testicular broth were added 400 cc. of water and the resulting mixture steamed for 20 minutes in an Arnold sterilizer to drive off the CHCl_3 . It was then filtered, the filtrate combined with enough water to make a liter and 1 gm. of K_2HPO_4 , 5 gm. of NaCl and 2.5 cc. of a 1.0 percent alcoholic solution of bromthymol blue were added. The pH was adjusted to 7.6. The bouillon was divided into 4 lots and to these 0.2 percent of glucose, arabinose, dulcitol and rhamnose, respectively, was added. The media were then placed in Durham fermentation tubes.

Maltose, rhamnose and xylose utilization was tested in the basic medium of Bitter, Weigmann and Habs (1926) which has the following composition:

Dipotassium phosphate	0.5 gm.
Ammonium sulfate	1.0 gm.
Sodium citrate	2.0 gm.
Sodium chloride	5.0 gm.
Bactopeptone	0.05gm.
Distilled water	1000.0 cc.

The sugars were added to make a concentration of 0.5 percent. Each lot was tubed in amounts of 2 cc. in 13x100 mm. tubes. All the above described media were sterilized at 15 pounds pressure for 12 minutes and those that contained agar were allowed to solidify in a slanting position.

Saline suspensions of the bacilli were employed in the inoculation of the tubes. In preparing the inoculum organisms from a 24-hour-old agar slant culture were added to sterile saline in amount sufficient to give a turbidity of 1 on the McFarland nephelometer scale. A 3 mm. loopful of the suspension was placed in each tube. Each culture to be tested was inoculated into the 12 media described above, and incubated at 37 C.

After a 20-hour incubation period one drop of a 0.5 percent alcoholic solution of methyl red was added to each tube of Bitter's medium. A yellow color was regarded as a negative test, a red color as a positive test. Tubes which developed an orange

color were recorded as doubtful. Readings were made on the testicular broth at 24- and at 48-hour intervals. Fermentation was indicated by a change of the bromthymol blue indicator to a yellow color and by the production of gas, anaerogenic strains excepted. The sodium ammonium phosphate agar, hereafter referred to simply as ammonium agar, was observed over a period of four days. Tests were considered positive when growth appeared and was accompanied by a change in the color of the indicator while negative tubes showed no growth or color change.

In the serological examination of the organisms the methods employed were largely those of Kauffmann (1934). Antigens for the determination of the somatic characters were prepared by the method of White (1926). Bacilli scraped from 24-hour old agar slant cultures were suspended in absolute alcohol and heated at 60 C. for 1 hour. The suspensions were centrifuged, the alcohol decanted and the bacilli resuspended in physiological saline solution. They were then tested on a spot plate with suitably diluted antisera representative of the various somatic antigens of the Kauffmann-White classification. Those cultures which belonged to group B were further examined for the presence of antigens I and V. Antiserum derived from *S. senftenberg* was diluted 1 to 2 and used to test for antigen I. *S. typhi-murium* antiserum which had been absorbed with *S. abortus-equi* to remove agglutinins for antigens IV and XII was used in a dilution of 1 to 5 to test for antigen V. In examining the flagellar antigens, 18-hour-old infusion broth cultures diluted with an equal amount of physiological salt solution containing 0.6 percent formalin were used as antigens. These antigens were titrated against antisera derived from the specific and nonspecific phases of *S. typhi-murium*. Tests for flagellar agglutination were read after incubation for 1 hour at 50 C. Only those cultures which exhibited specific and nonspecific phases typical of the species were included in the study. In some instances cultivation in semisolid agar containing specific or non-specific antiserum was used to isolate suppressed phases.

RESULTS

The results of the examination of the cultures are given in tables 1 and 2. In table 1 are included all those types which con-

tained antigen V, while table 2 is made up of strains which lacked antigen V. The latter cultures hereafter will be referred to simply as IV variants. While the separation of the organisms into 2 groups on the basis of their content of V antigen may seem an arbitrary method of treatment, a study of the sources of the bacilli reveals that it is justified. Table 1 describes the 298 cultures which possessed the typical *S. typhi-murium* somatic complex, only one of which was isolated from a pigeon. Table 2 describes 93 cultures of IV variants, 74, or 79.5 percent of which were from pigeons. There is a history to suggest that the two cultures included in outbreak 14, one of which was isolated from a duck, the other from a turkey, were of pigeon origin. Shortly before the disease made its appearance a sick pigeon flew into the poultry yard and spent some time there. When two or more cultures derived from a single, definite outbreak of disease were studied they were grouped together under outbreaks. When only one culture from an epizootic was available it was recorded as a single isolation. Each culture listed under the single isolations represents a different outbreak of infection and while a number of cultures derived from the same animal species and having the same biochemical and serological characteristics are grouped together for the sake of brevity, there are no known epizootic relationships among these strains.

Cultures from 132 outbreaks of disease in various species of domestic animals are listed in table 1. In only 41 of these infections was more than one culture available for study. In those outbreaks from which more than one strain was isolated, the number available for study varied from 2 to 25. Regardless of the number of cultures isolated from a given outbreak, all were alike in their biochemical and serological characteristics. In table 2 are included 93 strains of IV variants that were derived from 48 outbreaks of infection. In 14 of these outbreaks more than one culture was available for study. Here, as in table 1, microorganisms from the same outbreak were identical in their biochemical and serological characteristics. The determination of the presence or absence of antigen I in cultures, as suggested by Christensen (1937), was very helpful in the differentiation of bacilli which gave identical

reactions in the biochemical tests. Cultures from the same outbreak were always alike in the possession or the lack of this antigen.

The strains were divided into 41 biological types by the tests employed. Undoubtedly, the examination of a larger number of cultures or the use of additional tests would increase the number of types. Since all the bacteria from a single outbreak of infection were alike in their reactions to these tests, it is justifiable to conclude that in an epizootic in which all the infections arise from a common source, the cultures isolated from infected individuals will belong to the same biological type. The value of the division of *S. typhi-murium* into different types is obvious. While at first thought the multiplicity of types may seem confusing, their number adds to their value. If it is possible to establish a large number of types, the finding of a carrier of bacilli belonging to the same type as an epizootic strain becomes much more significant.

It is worthy of note that of the 391 cultures studied, 72 yielded negative tests with rhamnose in the Bitter medium. While this test was once recommended by Bitter, Weigmann and Habs as a means of distinguishing *S. typhi-murium* (rhamnose positive) from *S. paratyphi B* (rhamnose negative), the results obtained with this series of cultures demonstrate its inefficiency as a method of differentiation in these two species. The cultures which gave negative rhamnose tests in the Bitter medium were isolated from a number of different animal species and no host specificity can be attributed to them. Ten of the cultures studied were anaerogenic. These 10 strains were derived from two outbreaks of disease, one in guinea pigs and one in pigeons. In both instances all the cultures isolated from these outbreaks failed to produce gas from any of the fermentable substances on which they were tested.

It should be emphasized that in commenting on the biological types encountered in the study, no host specificity has been attributed to the types delineated. Since host specificity has been claimed for certain cultural types by Hohn and Herrmann and by Jansen (1937), the cultures have been divided into the types established when only the tests used by Hohn and Herrmann are considered. These types and the animal species from which the cultures were derived are given in table 3. All the biochem-

ical types listed by Hohn and Herrmann, as well as additional types which they did not encounter, are included in the table. With the exception of rabbits and pheasants, all the animal species from which cultures were available yielded the "full" type which Hohn and Herrmann consider ubiquitous. The small number of cultures derived from rabbits and pheasants renders insignificant this failure of the "full" type to appear in these species. The "rhamnose negative" type, whose connection with ducks is emphasized by Hohn and Herrmann, was found only 3 times, twice in turkeys and once in a pheasant. The "ammonia-weak," or pigeon type of Hohn and Herrmann, was represented by 19 cultures of which 11 were isolated from pigeons, 4 from turkeys, 3 from rabbits and 1 from a horse. In addition 12 cultures resembled the "ammonia-weak" type except for their failure to utilize rhamnose in testicular broth. While the latter did not exactly coincide with any of the types of Hohn and Herrmann, they must be classified with the "ammonia-weak" strains because they gave no evidence of growth on any of the ammonium agar mediums. Of these cultures, 10 were derived from turkeys and two from pigeons. The "guinea pig" type of Hohn and Herrmann is represented by only 2 cultures, one isolated from a turkey and one from a chicken. The remainder of the strains, only 16 in number, were divided into 5 different types which do not fit into the classification of Hohn and Herrmann. The majority of these 16 strains were isolated from turkeys and not more than 5 cultures fell into any one type.

Edwards (1936a) and Edwards and Bruner (1939) found that all the cultures in their possession which were derived from pigeons were IV variants and suggested that the lack of antigen V was a more reliable criterion for the detection of strains of pigeon origin than was the failure of the bacilli to develop on ammonium agar. Hohn and Herrmann and Jansen did not agree with this suggestion since they found that IV variants occurred in animals other than pigeons. In order to clarify the biochemical and serological properties of cultures from pigeons, tables 4 and 5 are included. In table 4 the cultures containing antigen V and those lacking this component are listed under the animal species from

which they were isolated. Of the 75 cultures isolated from pigeons, 74, or 98.5 percent, were IV variants. On the contrary, of 316 cultures isolated from other species of domestic animals, only 19, or 6.0 percent, were IV variants. Further, while only 19.1 percent of the total cultures studied were isolated from pigeons, 79.5 percent of the IV variants encountered were derived from pigeons. These figures indicate a significant relationship between IV variants and pigeons.

In table 5 the IV variants from various animal species are divided into biochemical types according to their reactions in the tests advocated by Hohn and Herrmann. While 74 of the 75 cultures isolated from pigeons are included in the table, it will be noted that only 11, or 14.8 percent, conform to the "ammonia-weak" type of Hohn and Herrmann. Returning to table 3, it may be seen that 339, or 86.7 percent, of the 391 cultures studied belonged to the "full" type. Of the 75 cultures isolated from pigeons, 60, or 80 percent, belonged to the "full" type. Such a slight difference does not seem significant.

All the bacilli which failed to develop on ammonium agar, or which produced only a minimal growth on the medium are included in table 6. Of the 31 cultures listed in the table, 1 were isolated from pigeons. In addition 3 were from rabbits which were in contact with infected pigeons. In the case of the remaining 17 cultures there is no history to suggest that pigeons were the source of infection. All of the "ammonia-weak" type isolated from pigeons or from animals in contact with infected pigeons, were IV variants. With the exception of one IV variant isolated from a turkey, the remaining cultures all contained antigen V. They were isolated from a horse, chickens and turkeys. Not all the cultures included in table 6 correspond exactly to the "ammonia-weak" type as pictured by Hohn and Herrmann. Their "ammonia-weak" pigeon type ferments all the substances tested in testicular broth while a number of the cultures in table 6 fail to ferment rhamnose. Some of the cultures resemble the variant strains included by Jansen in the "rhamnose-negative" type which is prevalent in ducks in Holland and western Germany. Aside from the cultures isolated from pigeons, however, there are five cul-

tures in the table which do correspond exactly to the "ammonia-weak" type of Hohn and Herrmann, thus demonstrating that this type may occur in other animals.

DISCUSSION

It is readily apparent that cultures of *S. typhi-murium* can be divided into a number of types by the biochemical and serological tests employed. Furthermore, all the strains from a given outbreak of infection react similarly to these tests. Thus there can be little doubt that these types are epizootically significant. The addition of tests for the fermentation of maltose, rhamnose and xylose in the basic medium of Bitter, Weigmann and Habs and the division of the organisms according to the constituent antigens of their somatic complex greatly increases the number of types over those established by the methods of Hohn and Herrmann. Anaerogenesis also serves to distinguish strains from different outbreaks of infection. This increase in the number of types delineated is desirable since the larger the number of types found, the more significant becomes the detection of carriers of the epizootic type.

That epizootically significant types have been established in this series of cultures hardly can be disputed. In the light of these findings the failure of Lerche (1937, 1939) to obtain similar results in the large group of strains which he studied is somewhat perplexing. It must be remembered that one important difference exists between the cultures studied here and Lerche's series. The writers' strains were taken from definite outbreaks of infection and were isolated at postmortem examination of animals that died of these infections. Lerche's cultures, on the contrary, were isolated not only from animals which died during outbreaks of infection but also in meat inspection and by systematic fecal examinations of all animals on premises where *S. typhi-murium* infection was known to be present. It is quite conceivable that different species of animals on a single farm should be infected with, or be carriers of, more than one strain of the bacillus. It is also possible that animals of the same species on a single farm could carry more than one type of the organism. In the experience of the writers it is not uncommon to find two or even three different *Salmonella*

species in one outbreak of infection. On one occasion three *Salmonella* species were recognized in a culture from an individual animal. Therefore it is not surprising that Lerche found more than one type of *S. typhi-murium* in animals from a single farm.

When it is considered that many of the cultures studied here were derived from young fowls which were purchased from commercial hatcheries where the offspring of numerous flocks were brought in contact, it is indeed remarkable that not more than one type of *S. typhi-murium* was recognized among strains from a single flock. In more than one instance mixed infections due to *S. typhi-murium* and other species were encountered. In outbreak 20 in table 1 are listed 25 cultures from turkeys. Twenty-six cultures were isolated from this outbreak, of which 25 were *S. typhi-murium* and one was *S. derby*. In another outbreak, *S. typhi-murium* and an undescribed type which has been designated as *S. californica* were recognized. Such findings do not detract from the value of the typing of *S. typhi-murium* cultures. Rather they emphasize the absolute necessity of the careful typing of every *Salmonella* culture. Both *S. derby* and *S. californica* possess somatic antigens of the same type as *S. typhi-murium*. If all the cultures from the two outbreaks mentioned above had not been thoroly examined, the cultures of *S. derby* and *S. californica* might have been included in the tables as aberrant types of *S. typhi-murium*.

While in the writers' experience the biological types extant in *S. typhi-murium* are valuable for the differentiation of strains from different outbreaks of the infection, they are of no importance in the determination of the host relationships of the bacilli. Jansen (1937) misinterpreted the work of Edwards (1936) on the presence of fermentative types within the species. This work was intended to demonstrate only that fermentative differences existed in different strains of the bacillus, and that in a single outbreak of infection all the cultures exhibited the same characteristics. Jansen was of the opinion that the work was intended to demonstrate host specificity in certain types. Altho the writers attribute no host specificity to any of the biochemical types which they have described, other workers have emphasized the relationship of certain biochemical varieties to particular animal hosts. The work

of Hohn and Herrmann on this subject has been reviewed. These workers, as well as Jansen, have emphasized the relationship between their "rhamnose-negative" type and ducks. While they admit the occurrence of the "full" type in ducks, they report that the majority of their cultures from these birds failed to ferment rhamnose. The writers are in no position to affirm or to deny the prevalence of "rhamnose-negative" strains in ducks in the Netherlands and Western Germany. However, it can be said with a fair degree of certainty that the "rhamnose-negative" type is not prevalent in ducks in the United States. The writers examined 25 cultures from ducks and none of them belonged to the "rhamnose-negative" type. This type does occur in this country. Three cultures which coincide exactly with the "rhamnose-negative" type described by Hohn and Herrmann were found. Two of these were isolated from turkeys and one from a pheasant. In addition, a number of non-rhamnose-fermenting cultures from turkeys and chickens were found which do not conform exactly to the "rhamnose-negative" type. They resemble rather closely the cultures Jansen found in ducks and called the "rhamnose-negative" type. The writers would not attribute infection of man in this country with non-rhamnose-fermenting cultures of *S. typhi-murium* to bacilli that originated in ducks.

The writers wish to take exception to the statements of Hohn and Herrmann and of Jansen that the "ammonia-weak" type occurs more frequently in pigeons than any other biochemical variety of the bacillus and that the recovery of this type in an outbreak of infection indicates that pigeons were directly or indirectly responsible for the disease. While it is true that in our series, "ammonia-weak" strains occurred more frequently in pigeons than in any other animal, such cultures comprise only 14.6 percent of the organisms isolated from those birds. On the contrary, 80 percent of the cultures isolated from pigeons belonged to the "full" type, a figure not significantly different from the 86.7 percent "full" type strains found among all the cultures studied. Further, the "ammonia-weak" type was found in infections of turkeys and horses where there was no history of contact with infected pigeons. While it is quite possible that pigeons were responsible for those

infections, Hohn and Herrmann and Jansen have disagreed with the suggestion of Edwards and Bruner (1939) that IV variants indicated infection of pigeon origin, because IV variants were occasionally found in other animals. The same objection may now be cited in regard to the contention of the European workers that "ammonia-weak" strains are of pigeon origin.

The cultures from animals studied by Hohn and Herrmann and by Jansen are not sufficiently numerous to justify any far-reaching conclusions in regard to the host relationships of the types found. It is obvious that the larger the number of cultures studied the more numerous will be the biochemical types established. A number of types not described by Hohn and Herrmann were observed in the strains studied by the writers. Among the types not described by the above-mentioned workers are several strains listed in table 6. Prominent among these are the cultures from turkeys which gave no evidence whatever of growth on ammonium agar and which failed to ferment rhamnose in testicular broth. They form an intermediate group between the "ammonia-weak" type and the "rhamnose-negative" type. That all are "ammonia-weak" cannot be denied. Only their failure to attack rhamnose distinguishes them from the "ammonia-weak" type of Hohn and Herrmann. Their "rhamnose-negative" type from ducks grows more readily on ammonium agar. The occurrence of these cultures with minimal biochemical differences emphasizes the difficulty of assigning a certain biochemical type to a specific host.

The study of a larger number of cultures also necessitates a modification of the conclusions previously reached by the writers (Edwards and Bruner, 1939) who suggested that IV variants were more likely to exhibit aberrant biochemical reactions than were typical strains. They attributed failure to grow on ammonium agar, anaerogenesis and negative Bitter reactions among cultures of *S. typhi-murium* to the biochemical peculiarities of IV variants. It is now apparent that such variant types also occur in serologically typical strains of the bacillus.

The writers are of the opinion that the lack of antigen V is a much more reliable indicator of pigeon origin than is the classification of a culture in the "ammonia-weak" type. As stated above,

only 14.6 percent of the pigeon strains belong to the "ammonia-weak" type. On the contrary, 98.5 percent of the pigeon strains were IV variants. Further, while 79.5 percent of all the IV variants studied were isolated from pigeons, only 68.4 percent of the "ammonia-weak" strains in the collection were isolated from pigeons. While there probably is no significant difference between the latter figures, at least they demonstrate that "ammonia-weak" strains occur just as frequently in animals other than pigeons as do IV variants. Hohn and Herrmann, as well as Jansen, admit that the "ammonia-weak" strains from pigeons are IV variants. Hohn and Herrmann further state that their "full" type cultures from pigeons are IV variants. Their objection to the differentiation of pigeon strains by the lack of antigen V is that such cultures occasionally occur in other animals. The appearance of IV variants in animals other than pigeons is to be expected. Hoffman and Edwards (1936) described the spontaneous transmission of these organisms from pigeons to rabbits. Lerche (1939a) emphasizes the role of the pigeon in the spread of *S. typhi-murium* among animals. It would be surprising if IV variants were not found in other species. Since the "ammonia-weak" type composes such a small percentage of the cultures isolated from pigeons in the United States and since it occasionally is found in other animals, it is obviously impractical to attempt the differentiation of strains of pigeon origin in this country by the method of Hohn and Herrmann. On the contrary, practically all cultures isolated from pigeons in this country are IV variants and since this type is found only rarely in animals having no contact with pigeons, it is logical to assume that the recognition of IV variants in an outbreak of infection indicates that pigeons were directly or indirectly concerned in its occurrence.

CONCLUSIONS

1. *S. typhi-murium* is divisible into a number of types by the biochemical and serological tests employed in the study.
2. The types established are epizootically significant and all the cultures from a single outbreak of the infection belong to the same type.

3. The non-rhamnose-fermenting strains which certain European workers have associated with ducks are not prevalent in ducks in the United States. They occur rarely and were found in turkeys and a pheasant.

4. The "ammonia-weak" strains which Hohn and Herrmann have associated with pigeons are found only occasionally in pigeons in the United States. They occur rarely in other animal species.

5. Practically all cultures isolated from pigeons in the United States lack antigen V of the Kauffmann-White schema. It is suggested that the lack of this antigen in a culture indicates that the outbreak of infection from which it was derived was directly or indirectly connected with infection of pigeons.

REFERENCES

- Bitter, L. Weigmann, F. and Habs, H. 1926 Muench. Med. Wochenschr., 73, 940.
 Braun, H. and Cahn-Bronner, C. E. 1922 Biochem. Ztschr., 131, 226 and 272.
 Bruner, D. W. and Edwards, P. R. 1939 J. Bact., 37, 365.
 Christensen, A. 1937 Ztschr. f. Hyg., 120, 121.
 Edwards, P. R. 1935 J. Bact., 30, 465.
 1936 J. Inf. Dis., 58, 229.
 1936a J. Hyg., 36, 348.
 Edwards, P. R. and Bruner, D. W. 1939 Amer. J. Hyg., 29, 24.
 Edwards, P. R. and Rettger, L. F. 1927 J. Bact., 13, 13.
 Habs, H. 1934 Ztschr. f. Hyg., 116, 537.
 Herrmann, W. 1936 Erg. d. ges. Med., 21, 239.
 Hohn, J. 1937 Zbt. f. Bakt., Abt. I, Orig., 140, Beih., 53.
 Hohn, J. and Herrmann, W. 1936 Ztschr. f. Hyg., 117, 722.
 1936a Ztschr. f. Hyg., 118, 656.
 1937 Ztschr. f. Hyg., 119, 369.
 1939 Ztschr. f. Hyg., 122, 227.
 Jansen, J. 1937 Ztschr. f. Hyg. u. Infekkr. d. Haust., 52, 11.
 Jensen, C. O. Quoted by Kristensen, M. and Henricksen, D. 1926.
 Kauffman, F. 1934 Ztsch. f. Hyg., 116, 368.
 Kristensen, M. and Bojlen, K. 1929 Zbt. f. Bakt., Abt. I, Orig., 114, 86.
 1936 Zbt. f. Bakt., Abt. I, Orig., 136, 294.
 Kristensen, M. and Henricksen, D. 1926 Acta path. et microbiol. Scand., 2, 289.
 Lerche, M. 1937 Zbt. f. Bakt., Abt. I, Orig., 140, Beih., 53.
 1939 Ztschr. f. Hyg., 122, 72.
 1939a Proc. 7th World's Poultry Cong., 274.
 Mandelbaum, M. 1908 Muench. Med. Wochenschr., 55, 19.
 Moltke, O. 1926 Acta path. et microbiol. Scand., 3, 711.
 Salmonella Subcommittee 1934 J. Hyg., 34, 333.
 Schiff, F. 1929 Zbt. f. Bakt., Abt. I, Orig., 110, Beih., 90.
 Schuetze, H. 1920 Lancet, i, 93.
 Vogelsang, Th. M. 1934 J. Inf. Dis., 55, 276.
 Warren, S. H. and Iredale, J. L. G. 1934 J. Hyg., 34, 203.
 White, P. B. 1925 Med. Res. Council. Gt. Brit., Spec. Rpt. Ser. No. 91.
 1926 Med. Res. Council. Gt. Brit., Spec. Rpt. Ser. No. 103.

Table 1. Biological characteristics of *S. typhi-murium*

Outbreak	Source	Number of cultures	Bitter medium			Testicular broth				Sodium ammonium phosphate agar					Soni antigen
			Maltose	Xylose	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Sodium citrate	
1	Ducks	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
2	Ducks	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
3	Ducks	12	+	+	+	++	++	++	++	+	+	+	+	+	I 1
4	Ducks	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
5	Ducks	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
6	Canaries	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
7	Canaries	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
8	Canaries	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
9	Chickens	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
10	Chickens	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
11	Chickens	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
12	Chickens	6	+	+	+	++	++	++	++	+	+	+	+	+	I 1
13	Turkeys	16	+	+	+	++	++	++	++	+	+	+	+	+	I 1
14	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
15	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
16	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
17	Turkeys	8	+	+	+	++	++	++	++	+	+	+	+	+	I 1
18	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
19	Turkeys	8	+	+	+	++	++	++	++	+	+	+	+	+	I 1
20	Turkeys	25	+	+	+	++	++	++	++	+	+	+	+	+	I 1
21	Turkeys	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
22	Turkeys	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
23	Turkeys	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
24	Turkeys	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
25	Turkeys	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
26	Turkeys	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
27	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
28	Turkeys	11	+	+	+	++	++	++	++	+	+	+	+	+	I 1
29	Turkeys	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
30	Turkeys	5	+	+	+	++	++	++	++	+	+	+	+	+	I 1
31	Turkeys	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
32	Turkeys	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
33	Turkeys	4	+	+	+	++	++	++	++	+	+	+	+	+	I 1
34	Turkeys	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
35	Horses	13	+	+	+	++	++	++	++	+	+	+	+	+	I 1
36	Mice	6	+	+	+	++	++	++	++	+	+	+	+	+	I 1
37	Rats	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
38	G. pigs	11	+	+	+	++	++	++	++	+	+	+	+	+	I 1
39	G. pigs	3	+	+	+	++	++	++	++	+	+	+	+	+	I 1
40	G. pigs	6	+	+	+	++	++	++	++	+	+	+	+	+	I 1
41	Sheep	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
Single isolations	Duck	1	+	+	+	++	++	++	++	+	+	+	+	+	I 1
	Duck	1	+	+	+	++	++	++	++	+	+	+	+	+	I 1
	Chickens	2	+	+	+	++	++	++	++	+	+	+	+	+	I 1
	Chicken	1	+	+	+	++	++	++	++	+	+	+	+	+	I 1
	Chickens	7	+	+	+	++	++	++	++	+	+	+	+	+	I 1

Table 1. (Continued) Biological characteristics of *S. typhi-murium*

	Source	Number of cultures	Bitter medium			Testicular broth				Sodium ammonium phosphate agar					Somatic antigens
			Maltose	Xylose	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Sodium citrate	
Single isolations	Chicken	1	+	—	+	++	++	++	++	+	+	+	+	+	I IV V
	Chicken	1	+	—	+	++	++	++	++	+	+	+	+	+	IV V
	Chicken	1	+	—	+	++	++	++	++	+	+	+	+	+	I IV V
	Turkeys	23	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Turkeys	7	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Turkeys	2	+	—	+	++	++	—	++	+	+	—	+	+	IV V
	Turkeys	2	+	—	+	++	++	—	++	+	+	—	+	+	IV V
	Turkeys	2	+	—	+	++	++	—	++	+	+	—	+	+	I IV V
	Turkey	1	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Turkey	1	+	—	—	++	++	++	—	+	+	+	—	+	IV V
	Turkeys	2	—	—	—	++	++	++	++	+	+	+	+	+	IV V
	Turkeys	3	—	—	—	++	++	++	++	—	—	—	—	—	IV V
	Turkey	1	—	—	—	++	++	++	++	—	—	—	—	—	IV V
	Turkey	1	+	—	+	++	++	++	++	+	+	+	—	+	IV V
	Turkey	1	+	—	—	++	++	++	++	—	—	—	—	—	IV V
Single isolations	Turkey	1	+	—	—	++	++	++	—	+	—	—	—	—	I IV V
	Turkey	1	+	—	—	++	++	++	—	+	—	—	—	—	IV V
	Turkey	1	—	—	—	++	++	++	—	+	—	—	—	—	IV V
	Turkey	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Turkeys	2	+	—	—	++	++	++	—	+	—	—	—	+	IV V
	Turkey	1	—	—	—	++	++	++	++	+	+	+	+	+	IV V
	Turkey	1	+	+	—	++	++	++	—	+	+	—	—	—	IV V
	Turkey	1	+	—	—	++	++	++	—	+	+	—	—	—	IV V
	Turkey	1	+	—	—	++	++	++	—	+	+	—	—	—	IV V
	Canary	1	+	—	+	++	++	++	++	+	+	+	+	+	I IV V
	Canary	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Canary	1	+	—	+	++	++	++	++	+	+	+	—	—	IV V
	Pheasant	1	+	—	—	++	++	++	++	+	+	—	—	—	IV V
	Partridge	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Pigeon	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
Single isolations	Mouse	1	—	—	+	++	++	++	++	+	+	+	+	+	I IV V
	Mouse	1	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Mouse	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Mouse	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Calf	1	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Dog	1	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Dog	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V
Single isolations	Fox	1	+	+	—	++	++	++	++	+	+	+	+	+	IV V
	Foxes	2	+	+	+	++	++	++	++	+	+	+	+	+	IV V
	Fox	1	+	—	+	++	++	++	++	+	+	+	+	+	I IV V
	Hog	1	+	+	+	++	++	++	++	+	+	+	+	+	I IV V
	Hogs	2	+	—	+	++	++	++	++	+	+	+	+	+	IV V
	Horse	1	—	—	—	++	++	++	++	—	—	—	—	—	I IV V
	G. pig	1	+	+	+	++	++	++	++	+	+	+	+	+	IV V

Key to symbols:

Bitter medium

+Methyl-red positive after 20 hours incubation

—Methyl-red negative after 20 hours incubation

Testicular broth

++Acid and gas production after 48 hours incubation

+Acid production without formation of gas after 48 hours incubation

—Failure to produce acid or gas after 48 hours incubation

Sodium ammonium phosphate agar

+Visible growth after 96 hours incubation

—No visible growth after 96 hours incubation

Table 2. Biological characteristics of IV variants of *S. typhi-murium*

Outbreak	Source	Number of cultures	Bitter medium			Testicular broth				Sodium ammonium phosphate agar				
			Maltose	Xylose	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Sodium citrate
1	Pigeons	4	—	—	+	++	++	++	++	+	+	+	+	+
2	Pigeons	10	—	—	—	++	++	++	++	+	+	+	+	+
3	Pigeons	2	—	—	—	++	++	++	++	+	+	+	+	+
4	Pigeons	4	—	—	+	++	++	++	++	+	+	+	+	+
5	Pigeons	11	—	—	+	++	++	++	++	+	+	+	+	+
6	Pigeons	7	—	—	+	++	++	++	++	+	+	+	+	+
7	Pigeons	2	—	—	+	++	++	++	++	+	+	+	+	+
8	Pigeon 1 }	4	—	—	—	++	++	++	++	—	—	—	—	—
9	Rabbits 3 }		—	—	—	++	++	++	++	+	+	+	+	+
10	Pigeons	2	—	—	+	++	++	++	++	+	+	+	+	+
11	Pigeons	5	—	—	+	++	++	++	++	+	+	+	+	+
12	Pigeons	2	—	—	+	++	++	++	++	+	+	+	+	+
13	Ducks	2	+	+	+	++	++	++	++	+	+	+	+	+
14	Goose 1 }	2	+	—	+	++	++	++	++	+	+	+	+	+
	Duck 1 }		+	—	+	++	++	++	++	+	+	+	+	+
Single isolations	Pigeons	3	—	—	—	++	++	++	++	+	+	+	+	+
	Pigeons	7	—	—	+	++	++	++	++	+	+	+	+	+
	Pigeons	9	—	—	—	++	++	++	++	—	—	—	—	—
	Pigeons	1	+	—	—	++	++	++	++	—	—	—	—	—
	Pigeon	1	—	—	—	++	++	++	++	+	+	+	+	+
	Pigeon	1	—	—	+	++	++	++	++	+	+	+	+	+
	Turkeys	3	+	+	—	++	++	++	++	+	+	+	+	+
	Turkey	1	+	+	—	++	++	++	++	—	—	—	—	—
	Turkey	1	+	+	—	++	++	++	++	+	+	+	+	+
	Chickens	2	+	—	—	++	++	++	++	+	+	+	+	+
	Chicken	1	—	—	+	++	++	++	++	+	+	+	+	+
	Horse	1	—	—	+	++	++	++	++	+	+	+	+	+
	Horse	1	+	+	+	++	++	++	++	+	+	+	+	+
	Calf	1	+	+	+	++	++	++	++	+	+	+	+	+
	Fox	1	+	+	+	++	++	++	++	+	+	+	+	+

Key to symbols:

Bitter medium

+Methyl-red positive after 20 hours incubation

—Methyl-red negative after 20 hours incubation

Testicular broth

++Acid and gas production after 48 hours incubation

+Acid production without formation of gas after 48 hours incubation

—Failure to produce acid or gas after 48 hours incubation

Sodium ammonium phosphate agar

+Visible growth after 96 hours incubation

—No visible growth after 96 hours incubation

Table 3. Zoological distribution of biochemical types of *S. typhi-murium*

Source	Types of Hohn and Hermann				Miscellaneous types*						Totals
	"Full" type	"Ammonia- weak" type	"Rhamnose- negative" type	"Guinea-pig" type	1	2	3	4	5	6	
Turkeys	156	4	2	1	10	5	2	1	1	1	183
Pigeons	60	11					4				75
Chickens	26			1	2			2			31
Ducks	25										25
Canaries	9										9
Horses	15	1									16
Mice	9										9
Rats	3										3
Guinea pigs	21										21
Sheep	2										2
Pheasant			1								1
Partridge	1										1
Calves	2										2
Dog	1										1
Foxes	5										5
Hogs	3										3
Rabbits		3									3
Goose	1										1
Totals	339	19	3	2	12	5	6	3	1	1	391

*Miscellaneous types:

1. "Ammonia weak" types which also failed to utilize rhamnose in testicular broth. The remaining miscellaneous types resembled the "full" type except in the following particulars:

2. Failed to utilize dulcitol in ammonium agar.
3. Failed to utilize dulcitol in ammonium agar and in testicular broth.
4. Failed to utilize rhamnose in ammonium agar.
5. Failed to utilize sodium citrate in ammonium agar.
6. Failed to utilize dulcitol and sodium citrate in ammonium agar.

Table 4. Zoological distribution of serological types of *S. typhi-murium*

Source	Total cultures	Cultures containing somatic antigens			
		IV and I	V and IV	V	IV and I
Turkeys	183			178	5
Pigeons	75			1	74
Chickens	31			28	3
Ducks	25			22	3
Canaries	9			9	0
Horses	16			14	2
Mice	9			9	0
Rats	3			3	0
Guinea pigs	21			21	0
Sheep	2			2	0
Pheasant	1			1	0
Partridge	1			1	0
Calves	2			1	1
Dog	1			1	0
Foxes	5			4	1
Hogs	3			3	0
Goose	1			0	1
Rabbits	3			0	3
Total	391			298	93

Table 5. Zoological distribution of biochemical types among IV variants of *S. typhi-murium*

Source	Types of Hohn and Hermann			Miscellaneous types*			Totals
	"Full" type	"Ammonia-weak" type	"Rhamnose-negative" type	1	2	3	
Pigeons	59	11			4		74
Rabbits		3					3
Turkeys	3		1	1			5
Chickens	1					2	3
Ducks	3						3
Horses	2						2
Calf	1						1
Fox	1						1
Goose	1						1
Totals	71	14	1	1	4	2	93

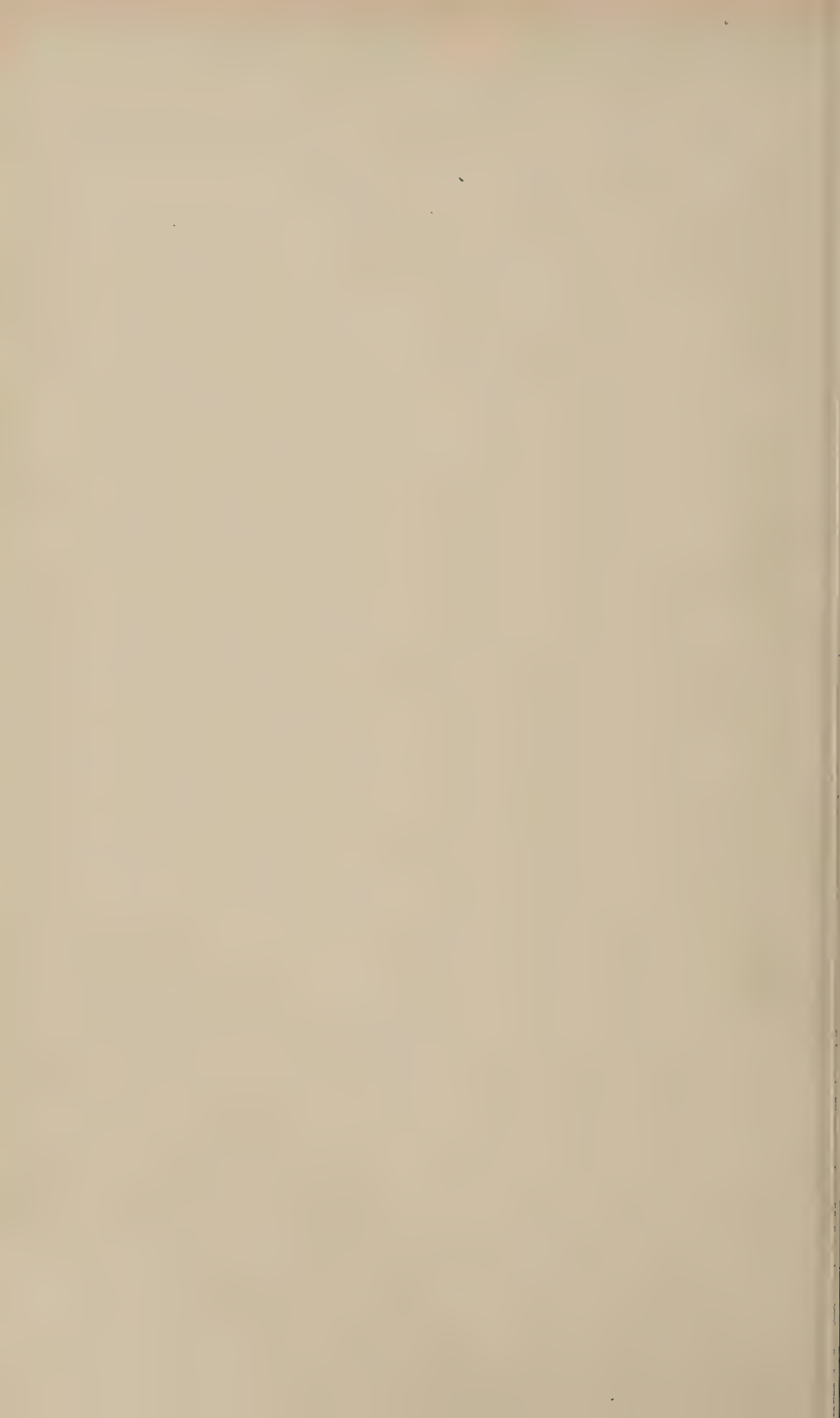
*Miscellaneous types

1. "Ammonia-weak" type which also failed to utilize rhamnose in testicular broth. The remaining miscellaneous types resembled the "full" type except in the following particulars:

- Failed to utilize dulcitol in ammonium agar and in testicular broth.
- Failed to utilize rhamnose in ammonium agar.

Table 6. Zoological distribution of "ammonia-weak" types of
S. typhi-murium

Number of outbreaks	Source	Number of cultures	Testicular broth				Sodium ammonium phosphate agar					Somatic antigens
			Glucose	Arabinose	Dulcitol	Rhamnose	Glucose	Arabinose	Dulcitol	Rhamnose	Sodium citrate	
1	Pigeon 1 Rabbits 3	4	++	++	++	++	-	-	-	-	-	IV
9	Pigeons	9	++	++	++	++	-	-	-	-	-	IV
1	Pigeon	1	++	++	++	++	-	-	-	+	+	IV
1	Turkey	1	++	++	++	---	-	-	-	-	-	IV
1	Horse	1	++	++	++	++	-	-	-	-	-	I IV V
3	Turkeys	3	++	++	++	++	-	-	-	-	-	IV V
1	Turkey	1	++	++	++	++	+	-	-	-	+	I IV V
3	Turkeys	5	++	++	++	---	-	-	-	-	-	IV V
1	Turkey	1	++	++	++	---	-	-	-	-	-	I IV V
1	Turkey	1	++	++	++	---	+	-	-	-	-	IV V
2	Turkeys	2	++	++	++	---	+	-	-	-	+	IV V
1	Chicken	1	++	++	++	---	+	-	-	-	+	I IV V
1	Chicken	1	++	++	++	---	+	-	-	-	+	IV V



Kentucky Agricultural Experiment Station

University of Kentucky

KENTUCKY WHITE GRUBS

BULLETIN NO. 401



Lexington, Kentucky

April, 1940

CONTENTS

	Page
Broods	74
The species of Kentucky May beetles	75
Distribution	77
By physical divisions of the state	79
By species	86
Life cycles	96
May beetles and their habits	97
Hibernation and movement in the soil	97
Flight habits	100
Sequence of emergence	100
Feeding preferences	103
By physical divisions of the state	103
By species	109
Reaction to lights	113
Mating	115
Egg laying	117
The egg stage	118
The larval stage	119
Life in the soil	120
Food preferences	123
The species of white grubs	124
Key to species	126
May-beetle pupation	131
Time of pupation	131
Length of pupal stage	132
Depths of pupation	133
Areas sampled	133
Species preferences	134
White grubs other than Phyllophaga	136
The Cyclocephalas	136
Life history	137
The Anomalas	139
The green June beetle	140
Natural enemies	141
Methods of study	143
Summary	149
Bibliography	150
Plates of genitalia	152

KENTUCKY WHITE GRUBS

By P. O. RITCHER*

Native white grubs, belonging principally to the genus *Phyllophaga*, annually cause much damage to pastures, corn, small grains, tree seedlings, potatoes, and strawberries in many sections of the United States and Canada. It is estimated that in 1933, in southern Wisconsin alone, 600,000 acres of bluegrass pasture were destroyed by grubs (Fluke and Ritcher, 1934). In some Carolina forest nurseries, the annual loss from grubs is estimated at 25 to 40 percent (Johnston and Eaton, 1939). In Kentucky, most of the visible injury has been limited to grub damage to strawberry patches and the stripping of shade and forest trees by the adults (figure 1). However, white grubs are widely distributed over the state and occur in such numbers in some areas that slight changes in climatic or other conditions may some day result in great destruction.

During the years between 1890 and 1929, H. Garman and various members of the Department of Entomology and Botany gathered records of grub and May-beetle attack and added specimens to the department collections. Early in 1933, at the suggestion of W. A. Price, C. O. Eddy began a study of white grubs on a Station project and tested light traps as a way to prevent the stripping of valuable shade trees by the beetles. Since April, 1936, as a continuation of the project, the writer has spent considerable time studying the biology and control of Kentucky white grubs in many parts of the state.

Various members of the Department of Entomology and Botany, members of the Horticulture Department, numerous students employed on N. Y. A. funds, county agents, high-school teachers, and many farmers of the state were of great help in the furtherance of the study. The most intensive study of white grubs was made in the vicinity of Lexington where the writer's observations include systematic collections during the flight periods of 1936, 1938, and 1939. Systematic collections were made in western Kentucky in 1937 while the writer was stationed at the Princeton Experiment Substation.

*The writer wishes to express his gratitude to Professor W. A. Price for his constant inspiration and help during the years involved in this study.

BROODS

In the region north of the Ohio river, entomologists recognize three broods of May beetles, A, B, and C. This results from the fact that the most common species have three-year cycles* and thus



FIGURE 1. Chinquapin oak stripped of foliage by May beetles, Lexington, 1939. Photo by Vaughn.

a given stage reappears at three-year intervals. Brood A, which was in flight in 1932, 1935, 1938 and will fly again in 1941, is the largest and most injurious. Brood B, in the north, is the smallest of the three broods while Brood C is large and injurious in certain limited areas. In many sections of the north where Brood A is the only important brood, grub damage and stripping by beetles occur only once in three years. Areas having two or all three broods in abundance are not so fortunate.

*Certain species of May beetles occurring in northern Wisconsin and at similar latitudes are said to require four years for their development.

As one goes farther south in the United States, there is a progressively longer growing season. This means that certain species of grubs requiring three years for their life cycle in the northern states may complete their cycle in Kentucky in two years. In other cases, in Kentucky, some grubs may mature in two years while others from eggs laid the same spring by the same species require three years. Also, some species of white grubs peculiar to Kentucky and states farther south, have two-year cycles.

In many parts of Kentucky, owing to the preponderance of grubs having a two-year cycle, the year-to-year occurrence of May beetles does not fit a three-brood pattern. The Inner Bluegrass Region of Kentucky appears to be one exception to this statement. Here, the dominant species, *Phyllophaga hirticula* (Knoch), usually maintains its three-year cycle as do certain of the less important species. In this area, at present, Brood B is the most important brood while Brood A is least important. As a result, grub damage in the Inner Bluegrass will probably be the greatest in 1940 and at three-year intervals thereafter.

THE SPECIES OF KENTUCKY MAY BEETLES

Thirty-six species of *Phyllophaga* are known to occur in Kentucky as ascertained by collections of over 30,000 May beetles, in 71 of the 120 counties (see map, figure 2).^{*} These species are *Ph. anxia* (Lec.), *Ph. arkansana* (Schffr.), *Ph. balia* (Say), *Ph. barda* (Hn.), *Ph. bipartita* (Hn.), *Ph. congrua* (Lec.), *Ph. corrosa* (Lec.), *Ph.*



FIGURE 2. Counties of Kentucky in which May beetles or white grubs were collected.

renulata (Froel.), *Ph. delata* (Horn), *Ph. drakii* (Kby.), *Ph. ephialda* (Say), *Ph. fervida* (Fab.), *Ph. forsteri* (Burm.), *Ph. fraterna*

^{*} The writer is indebted to Howard Tilson, Nursery Inspector, for help in making many of the collections.

(Harris), *Ph. fusca* (Froel.), *Ph. futilis* (Lec.), *Ph. glaberrima* (Blanch.), *Ph. hirticula* (Knoch), *Ph. hirtiventris* (Hn.), *Ph. hornii* (Sm.), *Ph. ilicis* (Knoch), *Ph. implicita* (Hn.), *Ph. inversa* (Hn.), *Ph. jonesi* Sanderson, *Ph. kentuckiana* Ritcher, *Ph. micans* (Knoch), *Ph. pearliae* Davis, *Ph. perlonga* Davis, *Ph. praetermissa* (Hn.), *Ph. profunda* (Blanch.), *Ph. prunina* (Lec.), *Ph. quercus* (Knoch), *Ph. rugosa* (Melsh.), *Ph. tristis* (Fab.), *Ph. vehemens* (Hn.), and *Ph. vilifrons* (Lec.).

The genus *Phyllophaga* to which the May beetles belong includes yellow-brown to blackish beetles averaging one-half to over an inch in length and bearing hair on the mesosternum. The antennae are lamellate and end in a three-jointed club. The tarsal claws bear a small tooth near the middle. Almost all the beetles of the genus are nocturnal in their habits.

The species of May beetles are most easily recognized by an examination of the male or female genitalia which ordinarily lie inside the abdomen. Those of the male may be removed with a dissecting needle. In the case of living or preserved females the genitalia are extruded when pressure is applied to the sides of the abdomen. For the convenience of other workers and to furnish a check on the writer's determinations, the genitalia of the Kentucky May beetles are illustrated with drawings (see plates 1-6). Four drawings are shown for most species. These include posterior, right and left views of the male genitalia, and a posterior view of the female genitalia. In certain cases where the male genitalia are symmetrical a ventral view is substituted for the right view.

Many species of May beetles may be recognized without recourse to the genitalia because of their body size, vestiture, color or distinctive structure. *Ph. tristis* is a very small May beetle averaging about one-half inch in length; *Ph. drakii*, in contrast, averages an inch in length. *Ph. crenulata*, *Ph. delata*, *Ph. hirticula*, *Ph. ilicis*, and *Ph. tristis* have hairy elytra (wing covers). *Ph. jonesi*, *Ph. micans*, and *Ph. prunina* are pruinose. *Ph. ephilida*, *Ph. futilis*, *Ph. praetermissa*, *Ph. quercus*, and *Ph. tristis* range from yellowish to reddish-brown in color while many other species are almost black. Males of *Ph. futilis* may be recognized by the peculiar shape of the fixed spur on the hind tibia; *Ph. hirtiventris* may be recognized by the median patch of hair on the under side of the abdomen.

DISTRIBUTION

Workers who have studied white grubs in other states have found that the species makeup of the white grub population varies from place to place. Forbes (1916), for example, divided the Illinois species into northern, central, and southern species. Luginbill (1928), speaking of South Carolina May beetles, states that species found in the lower part of the state or on the coast are not found in the upper regions, and vice versa. A number of causes for these variations have been suggested. Some have thought they were due to restricted flight habits of the adults. Others, such as Davis (1916) found several species most common in certain types of soil. Ritcher and Fluke (1935) thought that certain Wisconsin species were dependent on the distribution of preferred food plants.

Because of its intermediate latitude and sharp contrasts in topography, soil types, and plant distribution, Kentucky is a good state in which to follow shifts in the May beetle population. The writer found from a study of white grub distribution that many of the geographical regions of the state are characterized by fairly definite assemblages of species of Phyllophaga. Where the regions merge together there is usually a mingling of the characteristic species of the two regions. At the present time, by examining a small sample of white grubs or May beetles from an unknown section of the state, the writer can often tell the locality from which they came.

In general, there are thirteen physical divisions in Kentucky (figure 3). The influence of these is reflected in the topography of the seven main physiographic regions of the state. The diverse kinds of soil and topography have given rise in turn to eight main type-of-farming areas (figure 4).^{*} Some of these farming areas have a clearly marked homogeneity; others are less clearly defined. Certain areas are further subdivided into two or more distinct sub-types. In considering the grub population of the state, the species complexes of the various physical divisions will be discussed in connection with the associated farming regions. Following this, the distribution and importance of each species of Phyllophaga will be considered.

^{*}For further information on the soil areas and farming regions of the state the reader is referred to Kentucky Bulletin 193, by Averitt, Kentucky Bulletin 357, by Poundstone and Roth, and Kentucky Extension Circular 54, by Karraker, which are the sources of a number of the statements made in the discussion of the physical regions of the state.

PHYSICAL DIVISIONS OF KENTUCKY

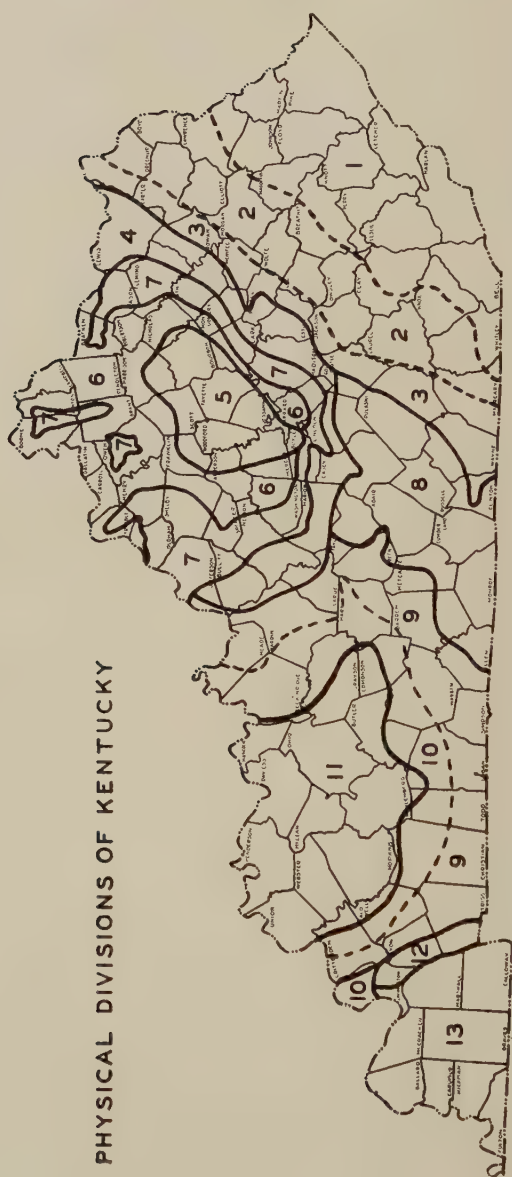


FIGURE 3. Physical divisions of Kentucky. 1. Eastern Coal Field, Eastern Belt. 2. Eastern Coal Field, Central Belt. 3. Eastern Coal Field, Western Belt. 4. Knobs. 5. Inner Bluegrass. 6. Hills of the Bluegrass. 7. Outer Bluegrass. 8. Eastern Pennyroyal. 9. Pennyroyal, limestone predominant. 10. Pennyroyal, sandstone predominant. 11. Western Coal Field. 12. Cumberland-Tennessee River area. 13. Purchase (Redrawn from Ky. Circular No. 54).

The Bluegrass

The Bluegrass, located in north central Kentucky, coincides closely with the boundaries of physical divisions Nos. 5, 6, and 7. It may be characterized as a livestock-tobacco region and much of the land is in pasture. The region is further divided into the Inner Bluegrass, Intermediate Bluegrass, and Outer Bluegrass sub-regions. Each of these has its own distinct assemblages of white grub species.

Inner Bluegrass Region. This area embraces some of the finest land in the United States.

The topography is gently rolling and the soils are of high fertility. Most of the farms are large and productive. The principal crops are tobacco, small grains, hogs, cattle, and sheep. Here are found most of the race-horse farms for which the state is celebrated. Much of the land is in bluegrass sod and the landscape is dotted with chinquapin and bur oak, walnut, sugar maple, and ash trees. Other common native trees are locust, wild cherry, sycamore, elm and



FIGURE 5. Adult of *Ph. hirticula*, important Kentucky May beetle, x 1½.

hackberry. A common, introduced tree, which is a favorite host of the May beetles occurring in this region, is the pin oak.

White grubs are very common in Inner Bluegrass pastures. Infestations average around 60,000 grubs per acre and are usually just below the number necessary to cause visible injury to sod. The species complex is characterized by the dominance of *Ph. hirticula* which constitutes more than 80 percent of the population (figures 5 and 6) and is responsible for most of the damage to sod and valuable oak trees. Other characteristic species are *Ph. hornii*, *Ph. tristis*, *Ph. futilis*, *Ph. inversa*, *Ph. fusca*, *Ph. rugosa*, and *Ph. kentuckiana*.*

* It is of interest that *Ph. hirticula* is also the dominant species in the fertile bluegrass region of southern Wisconsin and that many of the other species found there are identical with those characteristic of the Kentucky Inner Bluegrass.

TYPE OF FARMING AREAS IN KENTUCKY

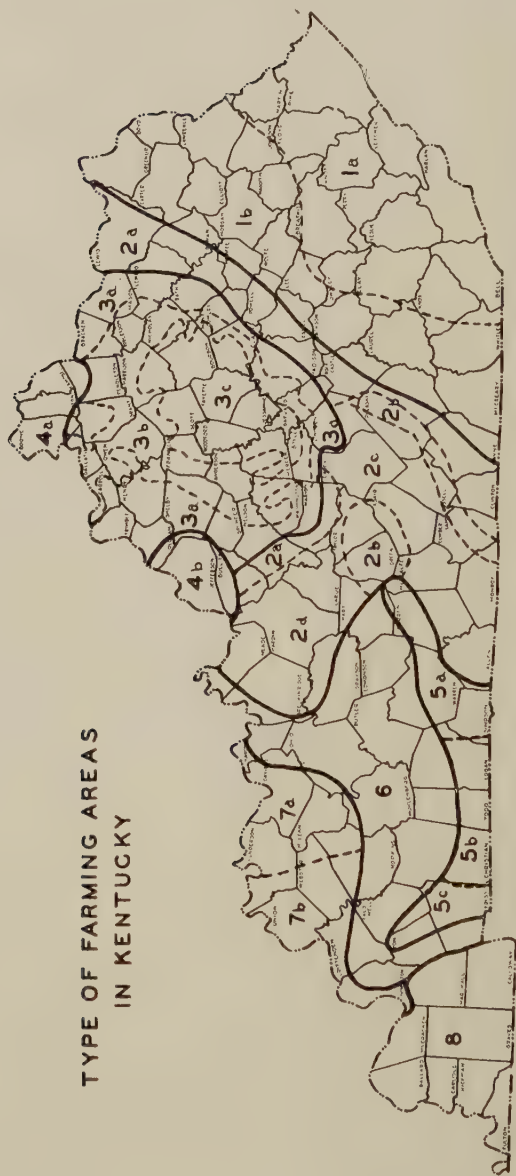


FIGURE 4. Type of farming in Kentucky. 1. Mountain; subsistence area. 2. Eastern Pennyroyal and Knobs; general farming area. 3. Bluegrass; livestock and tobacco area. 4. Urban-influence areas; truck crops, fruit, dairying. 5. Pennyroyal plain; tobacco-livestock area. 6. Western Coal Field; subsistence-tobacco area. 7. Lower Ohio Valley; corn, livestock and tobacco area. 8. Purchase region; general farming area (Taken from Ky. Bulletin No. 327).

Along the outer borders of the Inner Bluegrass, *Ph. ephilida* makes its appearance. Where a transition zone exists between the Inner Bluegrass and the Intermediate Bluegrass, *Ph. fraterna* is fairly common.

Intermediate Bluegrass Region. This, the poorest of the Bluegrass Regions, is quite hilly and rough. The soil is underlaid by shale and erodes quickly when subjected to cultivation. Much of the soil is low in organic matter and tends to be either too wet or too dry. Farming is often of the subsistence type and much of the area from necessity is in brushland or pasture. Common trees and shrubs are cedar, red and white oak, hickory, elm, persimmon, locust, willow, ash, redbud, crataegus, and sumac.

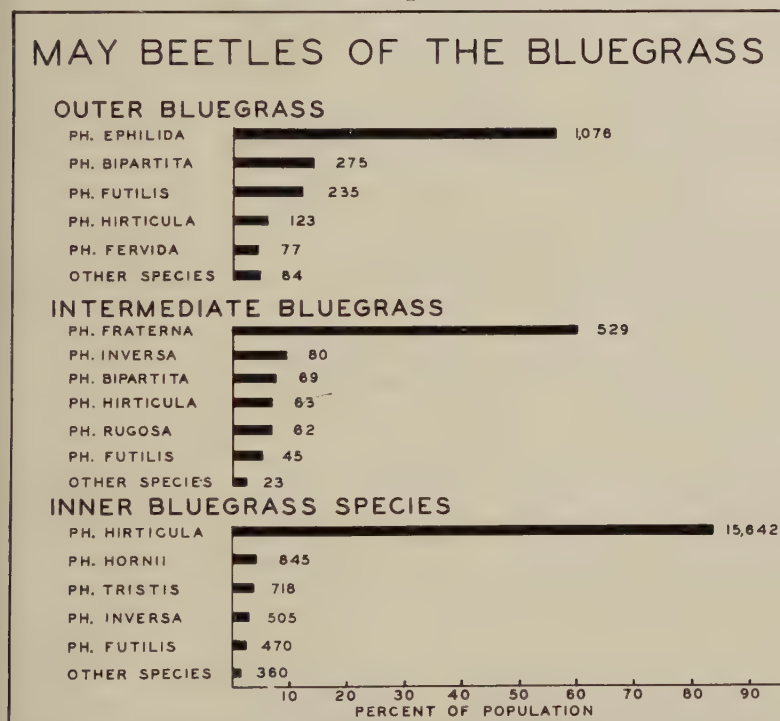


FIGURE 6. A comparison of the white grub faunas characteristic of the Outer, Intermediate and Inner Bluegrass.

Collections of May beetles from host plants in Garrard, Nicholas, Anderson, Scott, and Kenton counties,* combined with collec-

* The writer is indebted to H. Dorman for a number of collections made in Kenton county.

tions of grubs in Scott and Franklin counties show that the population is characterized by the dominance of *Ph. fraterna*. About 60 percent of the grubs and beetles found belonged to this species (figure 6). Other fairly common species are *Ph. inversa*, *Ph. hirticula*, and *Ph. futilis*. *Ph. bipartita* is common in Scott county and *Ph. rugosa* is fairly common in Nicholas and Kenton counties, both lying in the northeastern part of the region. Species which were found in small numbers are *Ph. perlonga*, *Ph. anxia*, *Ph. hornii*, *Ph. vehemens*, *Ph. implicita*, *Ph. crenulata*, and *Ph. tristis*.

Outer Bluegrass Region. This region is less fertile, on the whole, than the Inner Bluegrass but quite superior to the Intermediate Bluegrass. Its topography is considerably less rugged than the Intermediate Bluegrass and in certain areas is quite flat. The soil is suitable for general farming. Dairying and tobacco raising are important industries. Common trees are white oak, elm, ash, locust, walnut, sycamore, and willow.

Collections of white grubs and their adults show that the dominant species of the Outer Bluegrass is *Ph. ephilida* which makes up more than half the total population (figure 6). Other species which are commonly found are *Ph. bipartita*, *Ph. futilis*, *Ph. hirticula*, and *Ph. fervida*. The last is a highly characteristic Outer Bluegrass species and is not known to occur in the other two bluegrass regions.

The Knobs Region

The knobs form a semicircular belt lying to the west, south, and east of the Bluegrass. Their topography consists of separate hills or knobs sometimes 800 or 900 feet high, often separated by fairly wide, flat valleys. The soils of the hills and knobs have little farming value while some of the valley soils are fairly fertile. For the region as a whole, it is estimated that half is wooded and that crop land equals about 25 percent of the total acreage. Characteristic trees and shrubs are chestnut, laurel oak, white oak, post oak, red oak, persimmon, elm, black gum, sourwood and sumac.

White grubs appear to be scarce in the western Knob region and several collections of adults from host plants yielded only a very few beetles. In the southern Knob region of northern Taylor county, collection of grubs behind the plow yielded species identical, in most cases, with those collected in Fleming and Estill counties situated in the eastern Knob region. *Ph. fraterna* appears to

be the dominant species of the region and *Ph. balia*, a woodland species, was taken in all three areas. Other species found were *Ph. tristis*, *Ph. rugosa*, *Ph. forsteri*, *Ph. ilicis*, *Ph. crenulata*, *Ph. inversa*, *Ph. micans*, *Ph. corrossa*, *Ph. fusca*, *Ph. bipartita*, *Ph. quercus*, and *Ph. fervida*.

Eastern Pennyroyal

The Eastern Pennyroyal is located south of the Knob region and extends to the Tennessee line. It joins the mountainous Eastern Coalfield on the east and the Western Pennyroyal on the west. The Eastern Pennyroyal lacks the homogeneity of some of the other regions of the state and the varied soils and topography are reflected in wide differences in land value. Over 60 percent of the land is hilly or nearly mountainous. The more level land, which makes up less than 40 percent of the total area, is fairly well suited for general farming. Common trees and shrubs are persimmon, hickory, black oak, white oak, red oak, elm, walnut, dogwood, sassafras, and sumac.

Collections of May beetles in several localities in Adair, Russell, Rockcastle, and Pulaski counties indicate that the Eastern Pennyroyal is inhabited by its own peculiar group of Phyllophaga. Common species are *Ph. hirticula*, *Ph. crenulata*, *Ph. corrossa*, *Ph. micans*, *Ph. jonesi*, and *Ph. forsteri* in the order named with no one species dominant. *Ph. fusca*, *Ph. barda*, *Ph. fervida*, *Ph. ilicis*, *Ph. fraterna*, *Ph. anxia*, *Ph. tristis*, and *Ph. inversa*, were also found. Favored food plants were persimmon, blackberry, sycamore, elm, walnut, and various oaks.

Eastern Coalfield

The Eastern Coalfield includes the three major soil associations of the mountainous, southeastern third of the state. As a farming region, it is very poor except in favored valleys, and most of the farming is of a subsistence type. A large part of the area is wooded or at least in brush land. Common trees and shrubs are oaks, tulip poplar, chestnut, holly, persimmon, mountain laurel, sourwood, sycamore, magnolias, willows, hemlock and several species of pines.

Because of its inaccessibility and the scarcity of white grubs, except in favored spots, less is known about the Phyllophaga of this region than that of any other part of the state. Collections of

grubs or May beetles or both from fourteen of the mountain counties show that *Ph. ephilida*, *Ph. hirticula*, *Ph. fusca*, *Ph. crenulata*, *Ph. forsteri*, and *Ph. micans* are common species. *Ph. balia*, *Ph. hornii*, *Ph. drakii*, *Ph. anxia*, *Ph. kentuckiana*, *Ph. barda*, *Ph. tristis*, *Ph. fervida*, *Ph. vilifrons*, and *Ph. quercus* also occur. Adults of *Ph. hirticula* and *Ph. fusca* were most common in the lowlands while such species as *Ph. balia* and *Ph. forsteri* were associated with steep, wooded areas.

Western Kentucky

Western Kentucky includes the Western Coalfield, the Pennyroyal, the Cumberland-Tennessee River, and the Purchase regions. The May beetles inhabiting much of this large area include a number of species such as *Ph. profunda*, *Ph. prunina*, and *Ph. arkansana* which appear to be absent in eastern Kentucky. In spite of wide differences in soil and topography, collections made to date of white grubs and their adults show many more similarities between the species complexes of the regions of western Kentucky, than do those of eastern Kentucky.

Western Coalfield. This physical division, on the basis of farming regions, should be subdivided into two parts. The northern including Union, Henderson, Daviess and parts of adjacent counties is commonly called the Lower Ohio Valley. Farming in this area is of a highly commercial type with corn as a major crop. The topography is characterized by rolling uplands and broad, level bottoms and the top soil is of loessal origin. May beetles are probably of more importance in this subarea than is commonly realized. In 1938, widespread stripping of walnut, persimmon, and oak trees by May beetles was observed in Daviess county. Numerous specimens of *Ph. fervida* were dug from beneath a stripped walnut and a stripped persimmon tree. Other species which have been collected in the subarea are *Ph. crenulata*, *Ph. implicita*, *Ph. bipartita*, *Ph. futilis*, *Ph. micans*, *Ph. rugosa*, *Ph. tristis*, and *Ph. vehemens*.

The second and southern part of the Western Coalfield includes the coalfield proper and much of the farming is of a subsistence type. In some counties, the commercial production of strawberries has increased greatly in recent years. The topography in general is rolling to rough. A large proportion of the land is wooded. Common species of May beetles in this subregion are *Ph. micans*, *Ph. ephilida*, *Ph. crenulata*, *Ph. hirticula*, and *Ph. prunina*,

of which none is dominant. *Ph. fervida*, *Ph. arkansana*, *Ph. forsteri*, *Ph. ilicis*, *Ph. profunda*, and *Ph. fraterna* also occur.

The Western Pennyroyal. "Pennyroyal" is the name given to the level region extending along the southern border of Kentucky from Lyon and Caldwell counties in the west to Metcalfe and Green counties in the east. The southern and eastern part of this region is mostly underlaid with limestone and is placed in a separate, physical division (figure 3, No. 9). The area includes some of the best farming land in the state and large farms are common. This is a tobacco-livestock area and much of the land is in pasture.

The northern belt of the Western Pennyroyal is mostly underlaid with sandstone and is therefore considered to be a separate, physical division. There is considerable bottom land and flat to undulating upland in the area. Much of this is fairly suitable for general farming if properly fertilized. Farming in the rougher and steeper parts of the region tends to be of a subsistence nature and resembles that of the coalfield proper.

Numerous collections of May beetles and white grubs have been made in the Western Pennyroyal. Systematic collections were made thruout one flight season at Princeton in the western part of physical division No. 9. Common species of May beetles in the Western Pennyroyal, in general, are *Ph. crenulata*, *Ph. bipartita*, *Ph. arkansana*, *Ph. ephilida*, *Ph. implicita*, *Ph. hirticula*, and *Ph. praetermissa*. Other species occurring in smaller numbers are *Ph. profunda*, *Ph. fervida*, *Ph. tristis*, *Ph. micans*, *Ph. ilicis*, *Ph. prunina*, *Ph. quercus*, *Ph. hirtiventris*, *Ph. delata*, *Ph. jonesi*, *Ph. kentuckiana*, and *Ph. forsteri*. *Ph. bipartita* and *Ph. ephilida* were abundant in certain localities and rare or absent in others. *Ph. crenulata* was the dominant form in sod land on a number of Pennyroyal farms.

The Cumberland-Tennessee River Section. No collections of May beetles have been made in this small area. The region is mostly in forest and is of little or no value for farming.

The Jackson Purchase. The Purchase is an area of varied terrain including both upland and large bottom lands. Much of the land is in farms and about one-third of the farming area is given over to harvested crops. In McCracken and adjacent counties strawberry growing is of considerable importance.

Common species of May beetles in the Purchase are *Ph. ephilida*, *Ph. crenulata*, *Ph. profunda*, *Ph. micans*, *Ph. fraterna*, *Ph. implicita*, and *Ph. futilis*. *Ph. bipartita*, *Ph. fervida*, *Ph. prunina*, *Ph. delata*,

Ph. balia, *Ph. ilicis*, *Ph. tristis*, *Ph. congrua*, *Ph. hirtiventris*, *Ph. anxia*, and *Ph. perlonga* also occur. *Ph. ephilida* is responsible for much of the grub damage to strawberries in McCracken county. *Ph. implicita* was common in Hickman and Fulton counties but rare in McCracken.

Favored food plants of May beetles in the Jackson Purchase are persimmon, elm, blackberry and various species of oaks. Grub damage to strawberries is worse in fields near these food plants.

Distribution of White Grubs by Species

In order that the distribution of white grubs over the state may be clearly understood, each species will be taken up separately. The distribution of 24 species of Phyllophaga is illustrated by means of individual maps (figures 7-14).

Ph. anxia. A very rare species in Kentucky, collected from nine widely scattered localities (figure 13).

Ph. arkansana. A fairly common western Kentucky species occurring in the Western Coalfield and Pennyroyal regions (figure 7).

Ph. balia. An uncommon species; usually found associated with rough, wooded country (figure 14).

Ph. barda. A rare species; found in Wolfe, Rockcastle, Adair, Russell, and Pulaski counties (figure 9).

Ph. bipartita. A common Intermediate and Outer Bluegrass species; abundant in certain restricted, lowland areas of western Kentucky (figure 12).

Ph. congrua. A rare species recorded from Kenton, Fulton, and McCracken counties.

Ph. corrossa. Common in Adair and Russell counties of the eastern Pennyroyal; one adult reared from a grub collected in Taylor county.

Ph. crenulata. A widely distributed species; rarely found in the Bluegrass but exceedingly abundant in the western half of the state (figures 9 and 15b).

Ph. delata. An uncommon species taken in small numbers in McCracken, Fulton, and Barren counties.

Ph. drakii. A very rare species, recorded only from Breathitt county in the mountains.

Ph. ephilida. Abundant in the Outer Bluegrass and in certain parts of the Eastern Coalfield, Western Coalfield, Purchase, and Pennyroyal regions (figure 13).

Ph. fervida. Fairly common in the Outer Bluegrass and in the western part of the state (figures 14 and 15a).

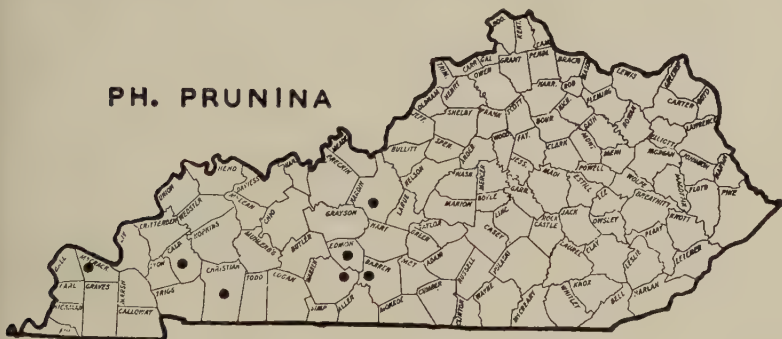
Ph. forsteri. Fairly common in several counties in the south-eastern part of the state (figure 13).

Ph. fraterna. The dominant Intermediate Bluegrass species. This species appears to be restricted to rough country. It is common in the Knob region and is found in several western Kentucky localities (figures 12 and 15d).

PH. ARKANSANA



PH. PRUNINA



PH. PROFUNDA

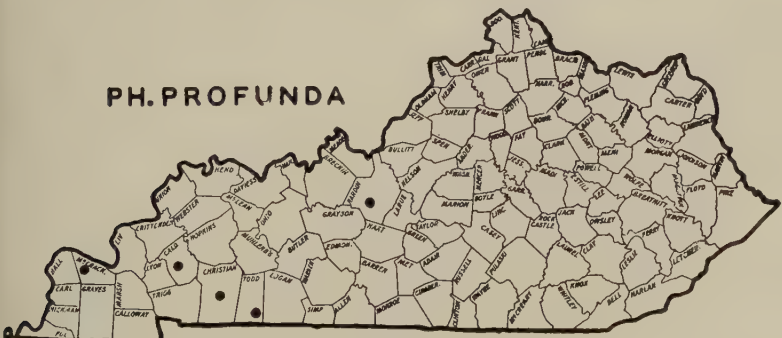


FIGURE 7. Distribution maps of *Ph. arkansana*, *Ph. prunina*, and *Ph. profunda*.

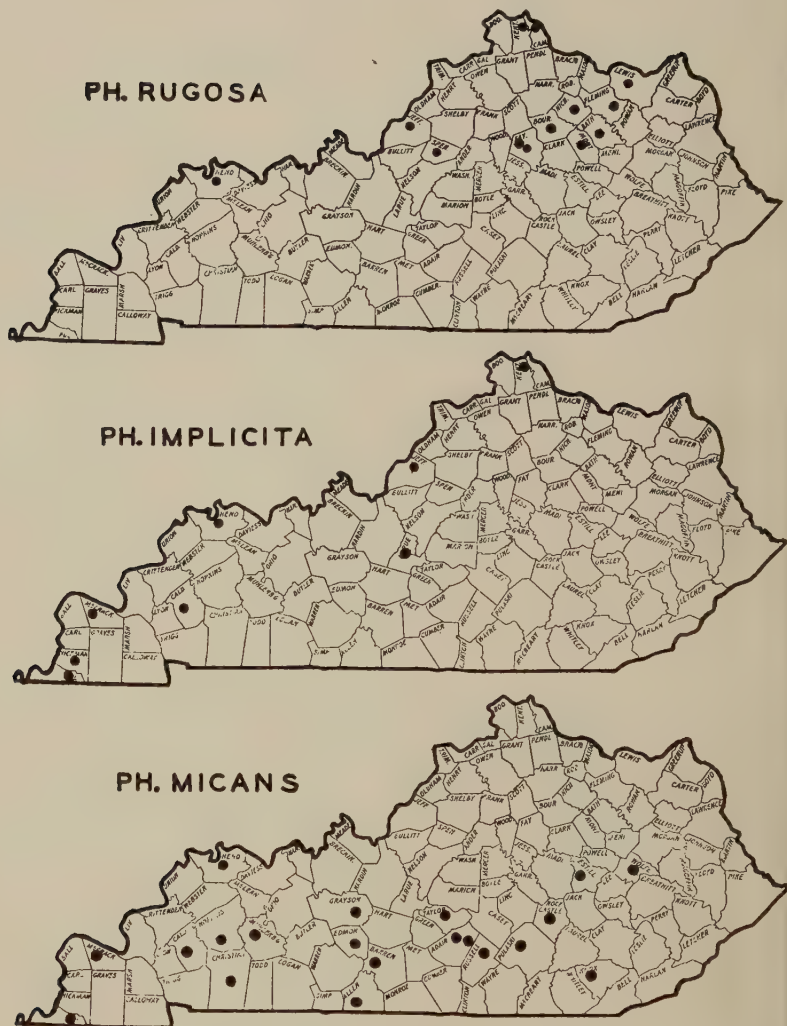


FIGURE 8. Distribution maps of *Ph. rugosa*, *Ph. implicita*, and *Ph. micans*.

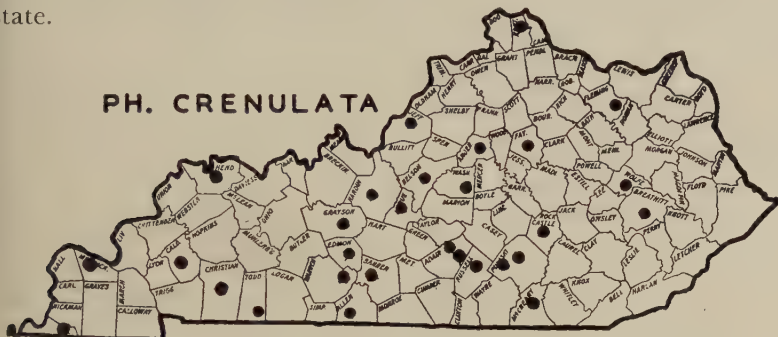
Ph. fusca. A characteristic species of the Inner Bluegrass; common in lowlands between the hills and mountains of southeastern Kentucky; also occurs in the Eastern Pennyroyal and occasionally in the Outer Bluegrass (figure 11).

Ph. futilis. Mainly a Bluegrass species occurring in all three subregions; fairly common in several counties of the Purchase (figure 10).

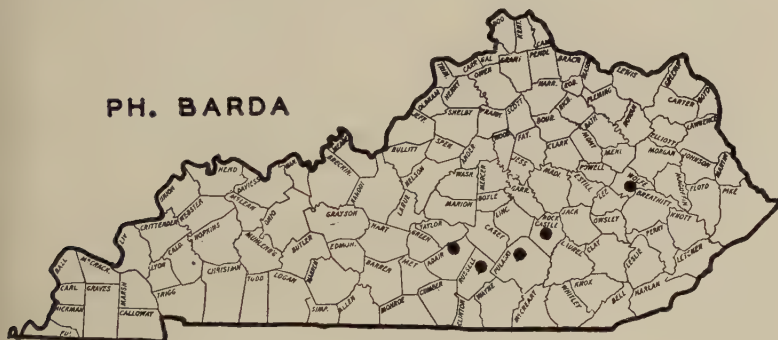
Ph. glaberrima. Not collected by the writer. Recorded from the state by J. B. Smith (1888).

Ph. hirticula. This species, one of the most important in Kentucky, is dominant in the Inner Bluegrass Region and common in the Outer Bluegrass (figure 10). It is widely distributed over the state.

PH. CRENULATA



PH. BARDA



PH. ILICIS

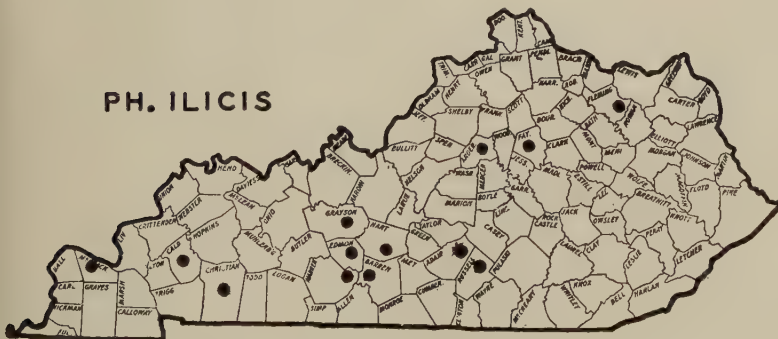


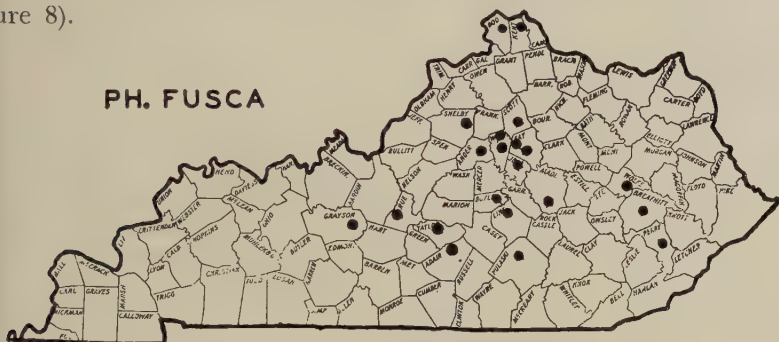
FIGURE 9. Distribution maps of *Ph. crenulata*, *Ph. barda*, and *Ph. ilicis*.

Inner Bluegrass; also found in the Intermediate Bluegrass and in Breathitt and Bell counties. (figure 11).

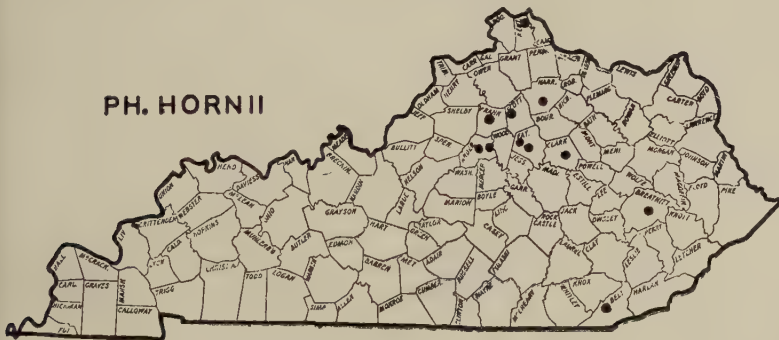
Ph. ilicis. A rather uncommon species which is probably widely distributed over the state. Very rare in the Bluegrass region (figure 9).

Ph. implicita. Abundant in some counties of western Kentucky and found occasionally in counties bordering the Ohio River (figure 8).

PH. FUSCA



PH. HORNII



PH. INVERSA

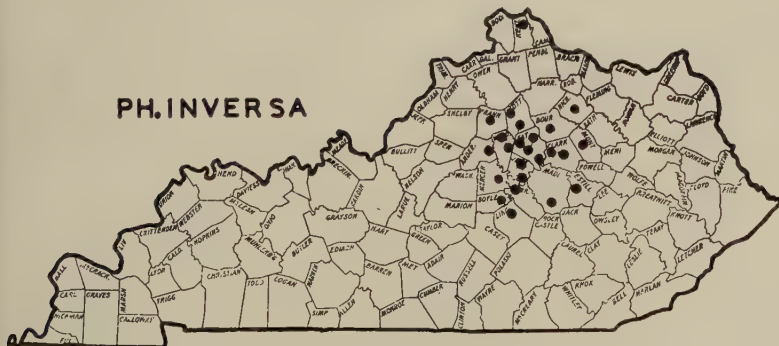


FIGURE 11. Distribution maps of *Ph. fusca*, *Ph. hornii*, and *Ph. inversa*.

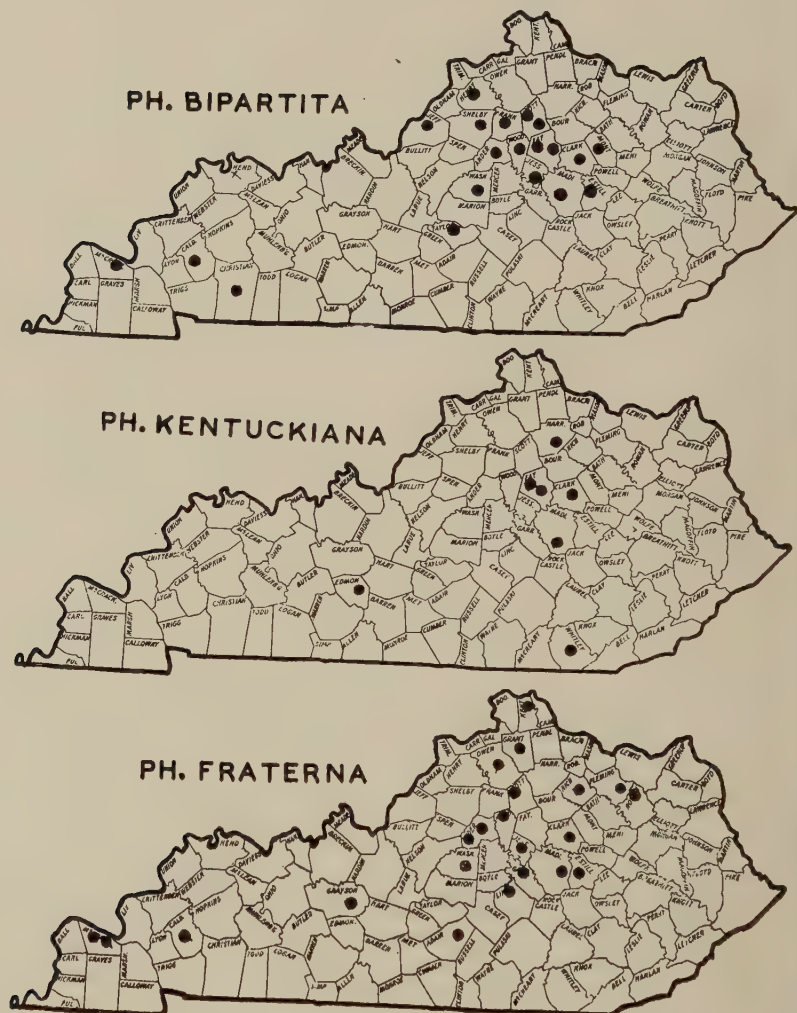


FIGURE 12. Distribution maps of *Ph. bipartita*, *Ph. kentuckiana*, and *Ph. fraterna*.

Ph. inversa. Almost entirely a Bluegrass species; common in the Inner and Intermediate but rare in the Outer Bluegrass. A few specimens have been taken in the adjoining Knob region (figure 11).

Ph. jonesi. This is a species recently described by Sanderson. It is closely related to *Ph. ilicis* and apparently grades into that species. Fairly common in Adair, Russell, Pulaski, and Barren counties.

Ph. kentuckiana. An eastern Kentucky species; sometimes fairly

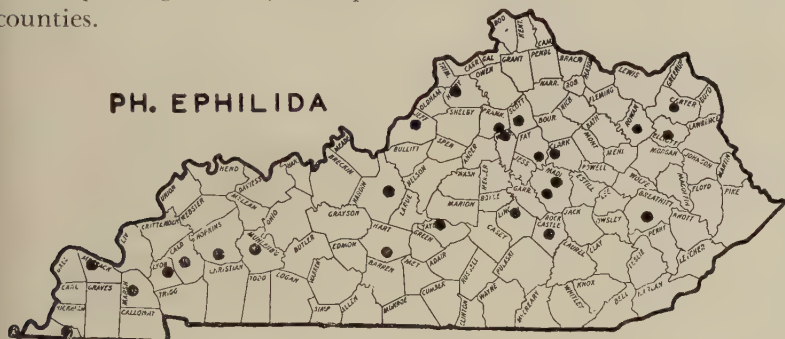
common in the Inner Bluegrass; also collected in Clark, Madison, Edmonson, and Whitley counties (figure 12).

Ph. micans. A common and widespread species over the southern half of the state; never taken in the Bluegrass (figures 8 and 15c).

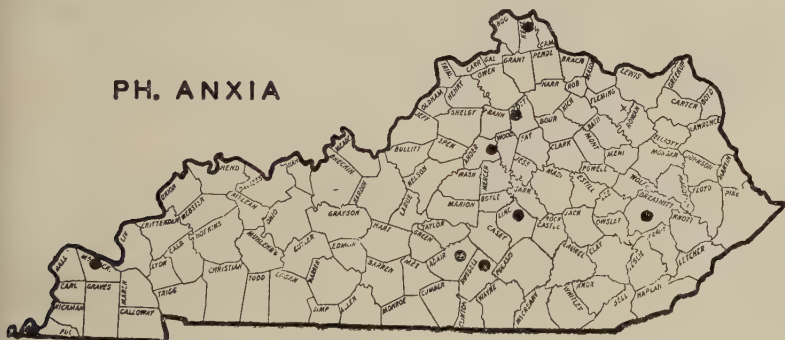
Ph. pearliae. Described by Davis from specimens collected in the bottoms near Louisville; not taken by the writer.

Ph. perlouga. A very rare species; taken in Scott and McCracken counties.

PH. EPHILIDA



PH. ANXIA



PH. FORSTERI



FIGURE 13. Distribution maps of *Ph. ephilida*, *Ph. anxia*, and *Ph. forsteri*.

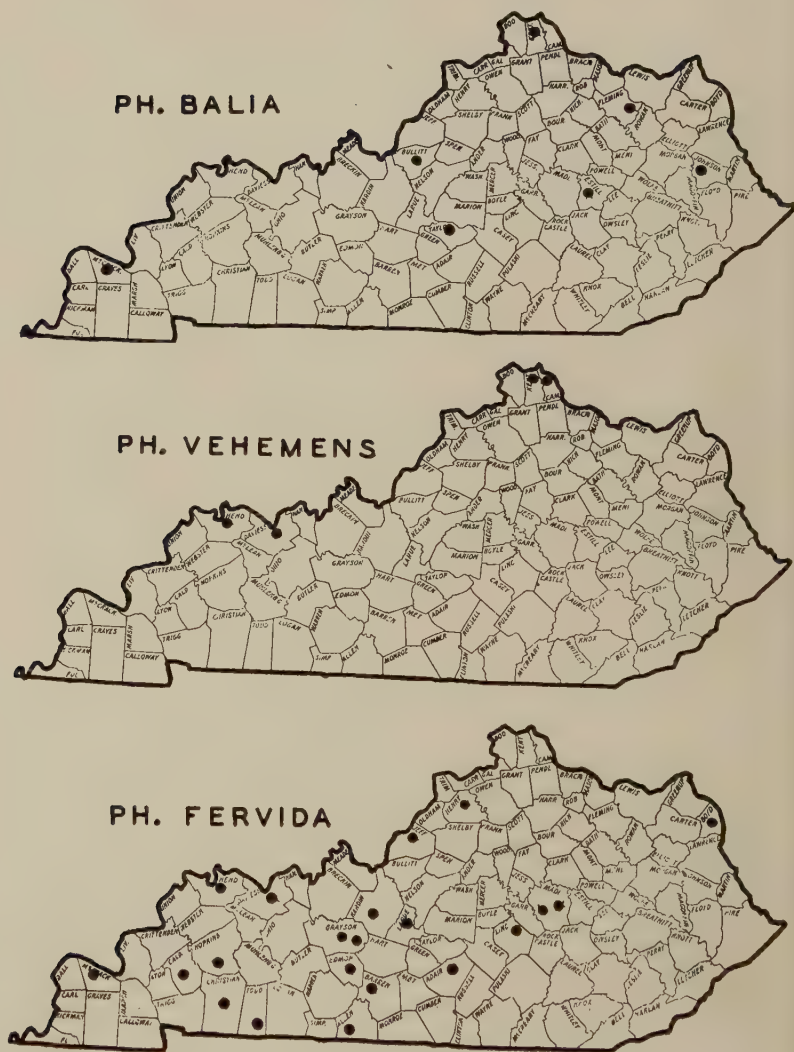


FIGURE 14. Distribution maps of *Ph. balia*, *Ph. vehemens*, and *Ph. fervida*.

Ph. praetermissa. A fairly common species confined to western Kentucky; taken in Caldwell, Christian, and Allen counties.

Ph. profunda. Found only in western Kentucky where it is fairly common (figure 7).

Ph. prunina. Another species so far taken only in western Kentucky; fairly common in sandy areas (figure 7).

Ph. quercus. A rare species, three adults having been taken, one in Caldwell and two in Lyon county. Several grubs of this species have been seen from Pike county and one grub from Taylor county was reared to the adult stage. It may be fairly common in the eastern mountains since it occurs in some numbers in eastern Tennessee.

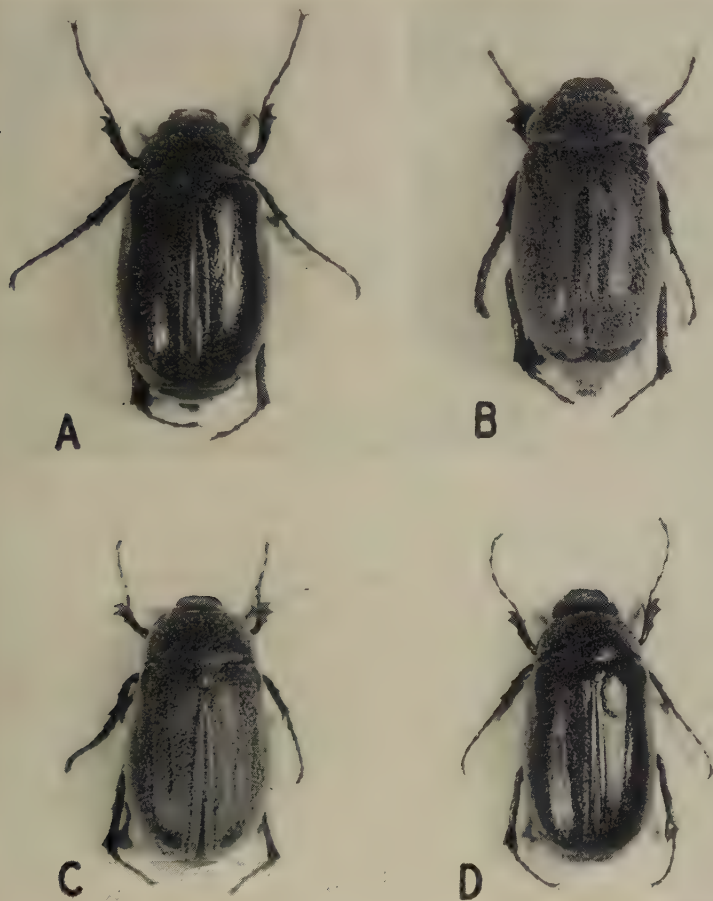


FIGURE 15. Adults of (a) *Ph. fervida*, (b) *Ph. crenulata*, (c) *Ph. micans*, and (d) *Ph. fraterna*. One and one half times natural size.

Ph. rugosa. A distinctly northern species confined to the northern third of the state. This species is fairly common in northeastern Kentucky (figure 8).

Ph. tristis. A species which is probably much more widely distributed than present records indicate. Adults are common in the Inner Bluegrass early in the flight season (figure 10).

Ph. vehemens. Taken only in or close to the river bottoms of the Ohio. Common in Kenton and Campbell counties (figure 14).

Ph. vilifrons. A rare species taken only in Kenton and Harlan counties.

LIFE CYCLES

Altho considerable time was given to a study of life cycles of the various species of May beetles, much remains to be done. Rearing work in which tile cages or screened boxes sunk in the soil were used proved unsatisfactory since grub development was retarded under such conditions. It was also observed that the length of the life cycle of a given species apparently varied in different localities. At present, large, earthenware pots are being used with more success.

Ph. hirticula, *Ph. rugosa*, *Ph. hornii*, *Ph. fusca*, and *Ph. crenulata* usually have three-year life cycles. That of *Ph. hirticula* has been worked out in detail and is illustrated in figure 16. It was found in 1939 that a few *Ph. hirticula* and *Ph. fusca* grubs became third-instar larvae during the first year of growth. This would indicate that the cycle of these particular individuals was shortened to two years. The acceleration seemed to be associated with conditions where the soil was very dry and the grass was short.

Species which often have a two- and sometimes a three-year life cycle are *Ph. futilis*, *Ph. bipartita*, and *Ph. inversa*. In the vicinity of Lexington, about 75 percent of the *Ph. futilis* grubs have a two-year cycle and 25 percent a three-year cycle. In the Intermediate Bluegrass Region, north of Lexington, many of the grubs of *Ph. bipartita* and *Ph. inversa* have a two-year cycle, molting twice the same year that the eggs are laid.

Ph. ephilida and *Ph. tristis* invariably have two-year cycles in Kentucky. The life cycle of *Ph. ephilida* and probably of *Ph. quercus* and *Ph. hirtiventris*, is quite different from that of the other Kentucky species. A striking thing is that the grubs of *Ph. ephilida* winter at extremely shallow depths. Another thing of importance is that grubs pupate in June and the adults emerge the same season. The life cycle has been worked out in some detail in the vicinity of Kingston and is illustrated in figure 17.

MAY BEETLES AND THEIR HABITS

Hibernation and Movement in the Soil. Most white grubs of species other than those of the *Ph. ephelida* group become adults in July or August. The transformation from the pupal to adult con-

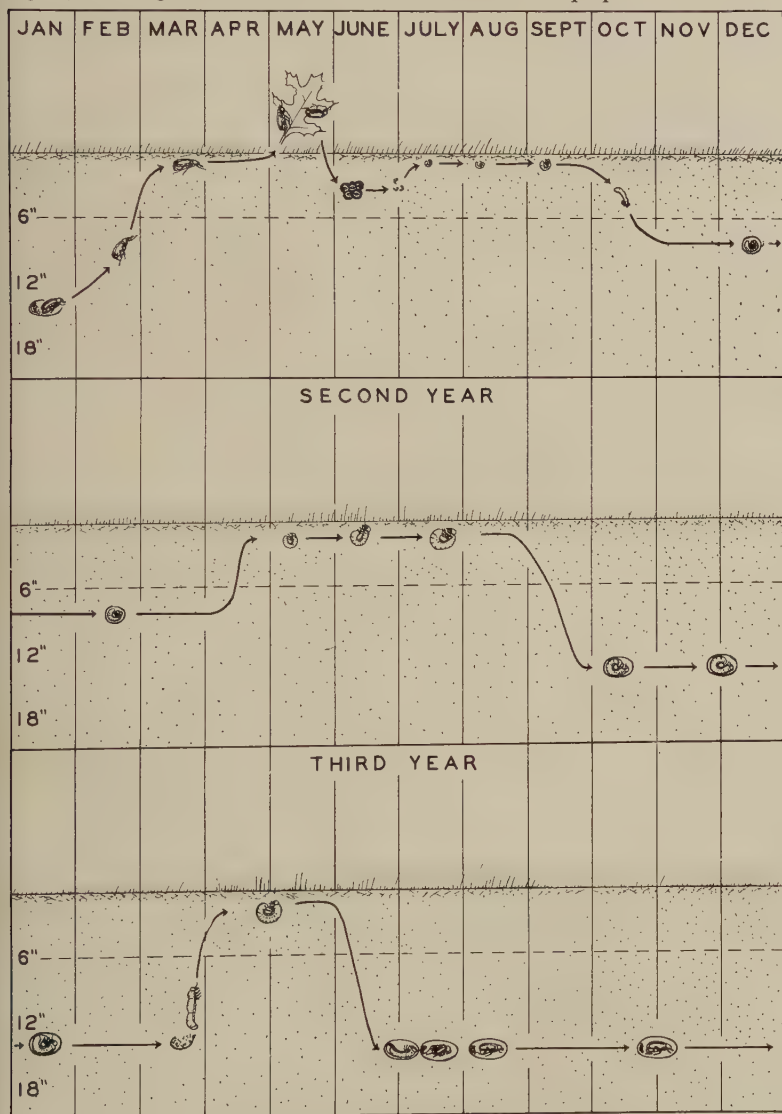


FIGURE 16. Life cycle of *Ph. hirticula*, common Kentucky white grub. Chart based on observations at Lexington from 1936 to 1940.

dition takes place in pupal cells at soil depths ranging from 3 to 23 inches, depending on the species involved. Some workers in other states have reported that certain species of May beetles move down from their pupal cells to spend the winter (Criddle, 1918). Hayes (1929) states that there is some reason for believing that many adults leave their pupal cells and burrow beneath the frost line.

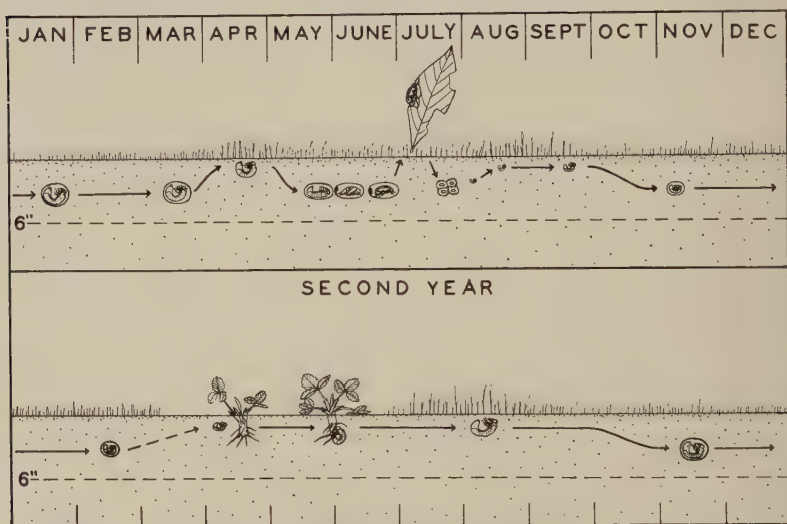


FIGURE 17. Life cycle of *Ph. ephilida*, common white grub in the Outer Bluegrass and a pest of strawberries in Western Kentucky.

From 1936 to 1940, a study was made of pupation depths. Much of the digging was done in the fall and winter and pupation records were secured at this time by digging for adult beetles and then locating the larval and pupal exuviae. In 1938, adults were so common in several localities that it was possible to get considerable data on their movements in the soil. Also, use was made of a screened area which had been stocked with third-instar grubs the previous spring. In 1938, between August 23 and November 12, a total of 127 *Ph. hirticula* adults were dug from the soil in the vicinity of Lexington. Of these, 108 were found in their pupal cells with larval and pupal exuviae.* The exuviae of the remaining 19 were not recovered. Since one fails to locate the exuviae of some beetles dug, even under the most favorable conditions, and since the mean

*In the vicinity of Lexington, *Ph. hirticula* grubs pupate at average depths of 12.3 to 15.6 inches (see section on pupation).

depths of the two groups were approximately the same, it is concluded that up to this time there was no movement from the pupal cells, either up or down.

On December 8, 7 adults of *Ph. hirticula* were dug in a high bottom pasture. All of these were found in their pupal cells but one adult was pointed up at a 45° angle. On January 3, 25 adult *Ph. hirticula* were dug in the area stocked with grubs the previous spring. Although 17 individuals were still in their pupal cells, 5 were lying in a nearly vertical position with their heads upward. Of the remaining 8 individuals, the cells of 6 were not located. The remaining 2 had each moved up an inch from their pupation sites.

On February 1, 16 *Ph. hirticula* adults were dug in the high bottom pasture. Six were found in their pupal cells and 5 were found which had moved up one to several inches from their pupal cells. On March 2, 1939, in the same locality, 2 adults of *Ph. hirticula* were found close to the surface of the soil. March 15, 12 *Ph. hirticula* adults were dug, the deepest of which was only 4.5 inches below the soil surface. Many of those at 2 to 3 inches were headed straight up and those at shallower depths were lying in pockets in the sod.

On February 12, 1940, 2 *Ph. hirticula* adults were dug from the soil at Lexington. One of these was in its pupal cell but was pointed up at a 45° angle. The second adult had moved up $11\frac{1}{2}$ inches from its pupation site located at a depth of $14\frac{1}{2}$ inches. March 7, one *Ph. hirticula* female was found just below the sod and a male of the same species was found at a depth of only $4\frac{1}{2}$ inches. March 13, 4 *Ph. hirticula* adults were dug. Two were in the sod and 2 others in the act of moving up, were at depths of 3 and 4 inches respectively.

It is concluded from these observations, that adults of *Ph. hirticula* do not move down from their pupal cells to spend the winter. Instead, in the vicinity of Lexington, they remain in their pupal cells at least until late in December. Movement up from pupal cells begins in January, in some years at least, and the first beetles arrive beneath the sod late in February or early in March.

Numerous observations were also made on the overwintering habits of *Ph. bipartita*, *Ph. inversa*, and *Ph. futilis*, and a few observations were made on *Ph. rugosa*, *Ph. fraterna*, *Ph. tristis*, and *Ph. fusca*. In no case in the course of winter diggings was any evidence found of downward movement from pupal cells. The be-

havior of *Ph. bipartita* and *Ph. fraterna* was very similar to that reported for *Ph. hirticula*. The first evidence of slight movement upward by these two species from pupal cells was found on January 7 in 1939. *Ph. inversa* and *Ph. futilis* remained in their pupal cells much longer than did *Ph. hirticula*, *Ph. bipartita* and *Ph. fraterna*. This was interesting since *Ph. inversa* and sometimes *Ph. futilis* pupate at shallow depths. Adults of *Ph. inversa* and *Ph. futilis* were often found in their pupal cells until late in March.

Flight Habits. In Kentucky, May beetles of some species begin to emerge from the soil early in April, the exact time varying from year to year. There is a definite sequence of emergence for the species found in any locality and adults of a few species may be found in flight until late in August. These latter are usually adults of species which normally pupate in June and fly the same season, such as *Ph. ephilida*.

During the day, May beetles remain hidden under rocks, leaves, trash or in the soil. Flight commences shortly before dusk with *Ph. tristis* beginning to fly while it is yet light. At first only a few beetles emerge but soon the air is full of flying forms. When in heavy flight there is a noise like a vast swarm of bees. The sound is loudest in the vicinity of preferred food plants, such as oak trees. Here the beetles soon settle and commence to feed.

A little after daybreak, the return flight to the soil occurs. Some beetles drop to the ground below the trees on which they were feeding and hide. Others fly to nearby fields. As a result of these nocturnal habits, the average person rarely notices May beetles unless the beetles happen to fly to lights, crash against the windshield of his car, or defoliate his shade trees.

May beetle flight is dependent upon weather conditions. When the air temperature is above 60° F. good flights occur and mating takes place. At temperatures much below 60° F., few beetles leave the soil and these few eat but little. It has been shown by Chamberlin in Wisconsin (1939) that some species, such as *Ph. fusca*, emerge in numbers at lower temperatures than do others.

Sequence of Emergence. Studies of emergence and May-beetle flight were carried on in the vicinity of Lexington by means of light traps and collections from food plants in 1936, 1938, and 1939. From a study of data so obtained it is apparent that the two species to emerge earliest in the Inner Bluegrass are *Ph. fusca* and

Ph. tristis. In the three years of observation their first appearance has always been in April. In 1938, a single male of *Ph. fusca* was first found in flight on April 14. As is apparent from tables 1 and 2*, in 1936 and 1939, the flight of *Ph. tristis* and *Ph. fusca* was practically over by May 10. Two other species which fly early in the season are *Ph. inversa* and *Ph. futilis*.

Table 1. Seasonal abundance of Brood B May beetles on host plants, Lexington, 1936.

Species	May 4	May 6	May 8	May 12	May 15	May 20	May 26	May 30	June 2	June 6	Totals
<i>Ph. hirticula</i>	6	122	166	180	8	12	38		6	21	559
<i>Ph. hornii</i>			1	8		15	111	2	36	49	222
<i>Ph. tristis</i>	27	57	42	7			1				134
<i>Ph. futilis</i>	2	10	10	12	1	4	3		1	1	44
<i>Ph. inversa</i>	1	19	4	1			1				26
<i>Ph. fusca</i>	1	18	1	1						1	22
<i>Ph. rugosa</i>		2	1	1			6			3	13
<i>Ph. kentuckiana</i>						1	5		2		8
Totals	37	228	225	210	9	32	165	2	45	75	1,028

Table 2. Seasonal abundance of Brood B May beetles on host plants, Lexington, 1939.

Species	April 27	April 30	May 5	May 9-10	May 17	May 24	May 30	June 5	June 15	Totals
<i>Ph. hirticula</i>	15	4	41	1104	851	194	377	167	63	2,816
<i>Ph. hornii</i>					43	50	284	97	48	522
<i>Ph. tristis</i>	90	36	88	107	20		3			344
<i>Ph. fusca</i>	41	3	14	37	4			1		100
<i>Ph. futilis</i>			4	21	3		1			29
<i>Ph. inversa</i>	2		14	9	1					26
<i>Ph. kentuckiana</i>					4	1	12	3	1	21
<i>Ph. rugosa</i>				1	9		4	1		15
<i>Ph. bipartita</i>							1			1
Totals	148	43	161	1,279	935	245	682	269	112	3,874

In the Inner Bluegrass, the dominant species and the species responsible for most of the stripping of trees is *Ph. hirticula*. This species usually makes its appearance late in April or early in May. Its appearance in destructive numbers, which usually begins about May 6, coincides with the time when *Ph. tristis* is past the peak of its emergence. Adults of *Ph. hirticula* are usually abundant throughout May and continue to fly during the early part of June.

*The figures given in these tables are for collections made from trees in Hillenmeyer's Nurseries, located three miles northwest of Lexington. Differences in the numbers caught in each collection or on each host are not always significant since the number of trees on which collections were made varied. Toward the latter part of the season to get even a few beetles, it was necessary to collect from many trees.

The two species to appear last in the vicinity of Lexington are *Ph. hornii* and *Ph. kentuckiana*. In ordinary seasons, these are rarely taken before the middle of May. *Ph. hornii* is a very common species from that time until the middle of June. *Ph. kentuckiana* flies during the same period but is not common.

Systematic collections of May beetles from food plants were made in 1937 at the Western Kentucky Experiment Substation located at Princeton (table 3). Flight began the third week in April and continued into August. The first species to appear was *Ph. praetermissa* which was first found in flight April 22, (taken in light trap). The last specimens of this common species were taken May 21. Other species which appeared in April were *Ph. tristis*,

Table 3. May-Beetle collections from host plants at Princeton, 1937.

Species	April 29	May 8-12	May 18-21	May 29- June 1	June 12	June 23	July 6	July 14	July 21-26	Aug 1	Totals
<i>Ph. praetermissa</i>	30	33	35								98
<i>Ph. tristis</i>	2	3	7	1							13
<i>Ph. bipartita</i>	17	11	76	7	1						112
<i>Ph. fervida</i>	1	10	7								18
<i>Ph. hirticula</i>		8	43	19			2	1			73
<i>Ph. crenulata</i>		2	30	3	2	2		3	1		43
<i>Ph. micans</i>		1	1								2
<i>Ph. ilicis</i>		1	2								3
<i>Ph. arkansana</i>		2	10								12
<i>Ph. prunina</i>			2								2
<i>Ph. implicita</i>			100	59	33	11	5	2	2		212
<i>Ph. profunda</i>			7								7
<i>Ph. hirtiventris</i>					1						1
<i>Ph. ephilida</i>							65	93	181	17	356
<i>Ph. quercus</i>									1		1
Totals	50	71	320	89	37	13	72	99	185	17	953

Ph. bipartita, and *Ph. fervida*. *Ph. hirticula*, *Ph. crenulata*, and *Ph. implicita* were important species which became abundant only after the middle of May. All three species were found occasionally as late as July. *Ph. ephilida*, the most common species taken, began to fly in July and its flight was still in progress in August.

In 1939, frequent collections of May beetles were made in the vicinity of Louisville in the Outer Bluegrass (table 4)*. The earliest species in this locality were apparently *Ph. futilis* and *Ph. fervida*. *Ph. rugosa* was common by the middle of May. *Ph. ephil-*

*Most of the collections were made by William Schneider, student; the remainder were made by Griffith Quinby of the State Board of Health.

Table 4. Seasonal abundance of May beetles near Louisville, 1939.

	May 6	May 9-10	May 16-17	May 23	May 28-30	June 30	July 3	July 5	July 11	July 14	July 17	Totals
<i>Ph. futilis</i>	58	42	68	6	12							186
<i>Ph. fervida</i>	8		2									10
<i>Ph. bipartita</i>	13		13		1							27
<i>Ph. rugosa</i>	2		36	7								45
<i>Ph. hirticula</i>			3		3							6
<i>Ph. crenulata</i>					4	1			1	1		7
<i>Ph. implicita</i>					1							1
<i>Ph. ephilida</i>						127	112	565	63	39	37	943
Totals	81	42	122	13	21	128	112	565	64	40	37	1,225

ida appeared late in June and was abundant the first two weeks in July.

Feeding Preferences. Studies made here and in other states show that the species of May beetles differ in their choice of food plants. Since the May beetles in the various regions of Kentucky vary widely as to species and these in turn vary in their periods of flight, the study of food preferences is of considerable economic importance. In the course of this study, May beetles were collected from food plants in most of the farming regions of the state. In order to give a detailed picture of feeding preferences and their economic implications, tabulated observations are presented for several representative areas and the various species are discussed in relation to preferred hosts.

In the Inner Bluegrass, hordes of May beetles often strip various species of trees in a very short time (figure 18). Bare and partly stripped oak trees were a common sight on farms in the area in May, 1936, and again in 1939 (figures 1 and 19). Certain other trees, such as maples, basswoods, wild cherries, and evergreens, showed no signs of attack (figures 19, 20, and 21). The reasons for these differences become apparent when we study the May beetles involved.

The earliest species to appear in numbers in the Inner Bluegrass is a small, light brown, hairy species, *Ph. tristis*. Altho it is almost exclusively an oak feeder, it causes only a very slight amount of damage because of its small numbers and small size.

Early in May, *Ph. hirticula*, the dominant species of the region, appears suddenly in large numbers. This May beetle has strong feeding preferences for various species of oaks with birch and elm

as second and third choices (table 5).* Species of oak most commonly attacked in this region are pin, red, bur, and chinquapin.



FIGURE 18. Shellbark hickory near Lexington stripped by May beetles. Photo by H. Garman.

The facts that *Ph. hirticula* is the dominant Inner Bluegrass species, that it prefers oaks, and that oaks are scattered in large acreages of fairly permanent bluegrass sod are some of the reasons

* *Ph. hirticula* is also fond of hickory and persimmon as shown by collections in other areas.

why the species is so destructive in certain years. The most important reason, however, is that the peak of emergence of *Ph. hirticula* often comes about May 6 when oak leaves are tender and only one or two inches in length. At such times, trees may be stripped liter-



FIGURE 19. Pin oak stripped by May beetles, May, 1939. Uninjured trees from left to right are maple, ash, and basswood (trimmed to ornamental shape). Photo by Vaughn.



FIGURE 20. Pin oak, center, stripped by May beetles. The tree to the right, by the fence, is a wild cherry and the one to the left is an ornamental ash. Photo by Vaughn.

ally overnight. Some leaves are simply devoured; many others are cut at the petiole and drop to the ground forming a carpet beneath the denuded trees.

Ph. hornii, a common species in the vicinity of Lexington later in May, shows strong preferences for pin oak, red oak, and birch. By the time it appears, however, foliage is so large and tough that little damage is noticeable.



FIGURE 21. Small pin oak defoliated by May beetles; unharmed maple nearby. Photo by Vaughn.

Other species commonly taken on food plants in the Inner Bluegrass are *Ph. futilis*, *Ph. inversa*, *Ph. fusca*, *Ph. rugosa*, and *Ph. kentuckiana* (table 5). *Ph. futilis* is a rather general feeder, being found on oaks, elm, hackberry, ash, and numerous other hosts. *Ph. inversa* is primarily an oak species. *Ph. fusca* is common on oaks and elm. *Ph. rugosa* is most common on oaks, birch, and sycamore. *Ph. kentuckiana* feeds on oaks almost exclusively. None of these species is numerous enough to cause much damage.

In the Intermediate Bluegrass, no stripping of trees by May beetles has been observed or reported. This may be because the dominant species, *Ph. fraterna*, is a general feeder and food plants are plentiful in relation to the amount of sod where grubs are apt

to become numerous. Common food plants of *Ph. fraterna* in this and other areas are white oak, red oak, elm, walnut, willow, hickory, crataegus, sycamore, plum, rose, and blackberry. Information as to the food plants of this and other Intermediate Bluegrass species in two representative localities may be found in tables 6 and 7.

Table 5. May beetle host preferences, Lexington, 1936-39

Species	Pin Oak	Red Oak	Bur Oak	Birch	Elm	Wal-nut	Syca-more	Hack-berry	Ash	Other hosts*	Totals	Percent of total
<i>Ph. hirticula</i>	1821	549	24	799	217	19	2			29	3,460	65.8
<i>Ph. hornii</i>	424	166		192	22	15	18		3		840	16.0
<i>Ph. tristis</i>	453	119	14		5					3	564	10.7
<i>Ph. futilis</i>	30	15	2	5	24	1		39	11	6	133	2.5
<i>Ph. fusca</i>	52	30		2	28	3			5	5	125	2.4
<i>Ph. inversa</i>	28	16	1	2	7	1					55	1.1
<i>Ph. rugosa</i>	13	6		16	1	1	5			2	44	.8
<i>Ph. kentuckiana</i>	23	11	2	1		1				1	39	.7
<i>Ph. bipartita</i>				1							1	
Totals	2,814	912	43	1,018	304	41	25	39	19	46	5,261	100.0

* These other hosts were Lombardy poplar, hard maple, Chinese elm, willow, cut-leaved birch, and paper birch.

Table 6. May beetles collected from food plants at Minorsville, May 8 and 29, 1939.

Species	Hick-ory	Elm	White oak	Wal-nut	Cra-tae-gus	Black-berry	Ash	Lo-cust	Red bud	Beech	Red oak	Per-sim-mon	Wil-low	Totals
<i>Ph. fraterna</i>	106	18	14	25	53	6	4		1	5	10	1	10	253
<i>Ph. inversa</i>	28	3		1	3	1					1			37
<i>Ph. futilis</i>	1	3	1		3	3	3	6	1				2	23
<i>Ph. bipartita</i>	10				1							4	1	16
<i>Ph. hirticula</i>	11											1		12
<i>Ph. hornii</i>	2		7									2		11
<i>Ph. anxia</i>						1	2							3
<i>Ph. perlonga</i>	1						1							2
Totals	159	24	22	26	60	11	10	6	2	5	11	8	13	357

Table 7. May beetles collected at Carlisle, May 19, 1939.

Species	Black-berry	Syca-more	Plum	Locust	Rose	Elm	Walnut	Willow	Peach	Hick-ory	Totals
<i>Ph. fraterna</i>	67	27	25	8	27	35	6	5	4	2	206
<i>Ph. rugosa</i>	3	9	3	3		8	2	2			30
<i>Ph. futilis</i>					1	5			1		7
<i>Ph. inversa</i>	4						1				5
<i>Ph. hirticula</i>	2										2
Totals	76	36	28	11	28	48	9	7	5	2	250

May beetles frequently strip trees in the Outer Bluegrass. Many stripped trees were seen between Richmond and Berea, in May, 1936. From table 8 it is seen that *Ph. hirticula* and *Ph. bipartita* were common species in this locality in May and early June of that

Table 8. May beetles taken near Berea, Kentucky, May 17 and June 3, 1936.

Species	White Oak	Willow	Walnut	Elm	Hickory	Totals
<i>Ph. bipartita</i>	75	130	14	16	1	236
<i>Ph. hirticula</i>	24	46	10	1	7	88
<i>Ph. fervida</i>	3	3	2	7		15
<i>Ph. inversa</i>		2				2
<i>Ph. fusca</i>				1		1
Totals	102	181	26	25	8	342

year. The two species were most abundant on white oak and willow at the times collections were made. *Ph. ephilida* adults are abundant in July in the Outer Bluegrass but cause little damage owing to the size and toughness of the leaves at that time (figure 22).



FIGURE 22. Pin oak leaves showing feeding places of *Ph. ephilida* adults.

In 1937, May beetles were collected from food plants thruout the flight season, at Princeton, in the western Pennyroyal. Trees on which May beetles commonly fed included willow oak, pin oak, red oak,

Spanish oak, elm, hackberry, willow, and persimmon. Information on the food plants of 15 species of May beetles in this area is contained in table 9. Information on the food plants of May beetles in the Purchase region is found in table 10.

Table 9. May-beetle collections from host plants at Princeton Substation, 1937.

Species	Willow oak	Red oak	Pin oak	Spanish oak	Elm	Hackberry	Willow	Persimmon	Other hosts*	Miscellaneous	Totals
<i>Ph. ephilida</i>	58	46	133	5	29	8	45	21	11		356
<i>Ph. implicata</i>	1			3	31	19	169		2		225
<i>Ph. bipartita</i>	11	4	26	55	9	3	1	1	4	2	116
<i>Ph. praetermissa</i>	33		37	23	3				6	1	103
<i>Ph. hirticula</i>	18	8	22	9	5	6	6	4	2	3	83
<i>Ph. crenulata</i>	4	1	2	19	7	7	5	19	8	6	78
<i>Ph. fervida</i>	3		6	2	2		1	1	9	2	26
<i>Ph. prunina</i>		1	3	2			1		6	12	25
<i>Ph. profunda</i>	1	1		6					4	4	16
<i>Ph. tristis</i>	4		4	5					1	1	15
<i>Ph. arkansana</i>	2		3	1	1				5	1	13
<i>Ph. micans</i>	1	1		2				4	1	3	12
<i>Ph. ilicis</i>	2	1		1					1		5
<i>Ph. fraterna</i>	2							1			3
<i>Ph. hirtiventris</i>					1						1
<i>Ph. quercus</i>	1										1
Totals	141	63	236	133	88	43	228	51	60	35	1,078

* These other hosts were post oak, white oak, hard maple, ash, hickory, dogwood, red bud, cultivated cherry, and blackberry.

Feeding Preference By Species

In order to present a better picture of the food preferences of Kentucky May beetles, each species will be considered separately with special mention of the food plants of the most abundant species. Following this, host plants will be discussed and their susceptibility to May-beetle attack considered.

Ph. anxia. Taken on ash, willow, persimmon, oak, sumac, and blackberry.

Ph. arkansana. Prefers oaks and persimmon; also taken on elm, ash, black gum, and hickory.

Ph. balia. Found feeding on chestnut oak (*Q. prinus*) and hickory.

Ph. barda. Collected from persimmon, hickory, and oak.

Ph. bipartita. Prefers white oak, pin oak, Spanish oak, elm, willow, and plum; collected also from hickory, persimmon, willow oak, red oak, post oak, walnut, crataegus, hackberry, hard maple, Chinese poplar, locust and blackberry.

Ph. congrua. None collected from food plants.

Ph. corrosa. Prefers hickory and blackberry; also taken on persimmon and oak.

Ph. crenulata. Strong preferences for persimmon and elm; collected also on willow oak, pin oak, red oak, Spanish oak, hackberry, redbud, willow, winged elm, hickory, sycamore, plum, black gum, sassafras, dogwood, box elder, crataegus, hibiscus, mock orange, and blackberry.

Table 10. May beetle collections at Kevil, 1937-1939.

Species	Spanish oak	Red oak	Post oak	White oak	Elm	Black-berry	Persimmon	Hickory	Miscellaneous*	Totals
<i>Ph. crenulata</i>	1				38	9	4	1	2	55
<i>Ph. ephilida</i>									54	54
<i>Ph. profunda</i>		1			5	26	1			33
<i>Ph. fraterna</i>	2	5	3		4	9	1			24
<i>Ph. tristis</i>	5	11	1	2		1				20
<i>Ph. micans</i>		6	1			2	1		5	15
<i>Ph. prunina</i>		1				4			1	6
<i>Ph. fervida</i>		1					1			2
<i>Ph. delata</i>						1				1
<i>Ph. balia</i>								1		1
<i>Ph. implicita</i>							1			1
<i>Ph. ilicis</i>									1	1
Totals	8	25	5	2	47	52	9	2	63	213

* The specimens of *Ph. ephilida* were dug from beneath hickory and persimmon trees on July 28, 1937.

Ph. delata. Collected from persimmon, sassafras, and blackberry.

Ph. drakii. Collected from black gum.

Ph. ephilida. A general feeder, very common on willow oak, pin oak, red oak, persimmon, elm, willow, locust, cultivated apple, cultivated plum; also feeds on Spanish oak, hackberry, walnut, pecan, wild cherry, dogwood, redbud, cultivated cherry, and cultivated pear.

Ph. fervida. Shows preferences for ash and elm; also taken on white oak, willow oak, pin oak, Spanish oak, red oak, willow, hard maple, persimmon, plum, black gum, hickory, walnut, and blackberry.

Ph. forsteri. Taken most frequently from persimmon and oak; also found feeding on hickory, walnut, willow, crataegus, sumac, and blackberry.

Ph. fraterna. This species is a very general feeder; found most commonly on white oak, red oak, hickory, elm, walnut, crataegus, willow, sycamore, plum, rose, and blackberry. It also feeds on willow oak, post oak, Spanish oak, chestnut oak, peach, ash, redbud, beech, and persimmon.

Ph. fusca. Prefers pin and red oak and elm; also feeds on ash, birch, walnut, plum, persimmon, willow, and black gum.

Ph. futilis. Prefers pin oak, elm, and hackberry. This species also feeds on locust, peach, hickory, white oak, crataegus, redbud, willow, plum, Chinese elm, camperdown elm, hard maple, post oak, chinquapin oak, cultivated apple, ash, osage orange, blackberry, elderberry, and rose.

Ph. glaberrima. No specimens of this species have been collected by the writer.

Ph. hirticula. This species has strong feeding preferences for oaks and hickory. The species of oaks most subject to attack are pin, red, bur, white, and chinquapin. English oak (*Q. robur*) is shunned and no specimens of *Ph. hirticula* were found feeding on this imported species in the same yard where pin and red oaks were badly stripped. In addition to oaks and hickory, *Ph. hirticula* is also fond of birch, willow, elm and persimmon. Birch and willow, at least, are more commonly preferred later in May when oak foliage is tougher and not so attractive. This species has also been taken on Spanish oak, post oak, walnut, hackberry, camperdown elm, Lombardy poplar, mulberry, pear, osage orange, plum, maple, blackberry, and elderberry.

Ph. hirtiventris. One male was found feeding on elm.

Ph. hornii. Prefers pin oak, red oak, and birch; also found feeding on white oak, hickory, persimmon, willow, walnut, elm, blackberry, sycamore, and ash.

Ph. ilicis. Found feeding on willow oak, Spanish oak, red oak, white oak, hickory, sycamore, persimmon, and sassafras.

Ph. implicita. This species' favorite food plant is willow. It is fairly common on elm, hackberry, and persimmon. It has been taken in small numbers on willow oak, pin oak, Spanish oak, dogwood, redbud, Chinese poplar, Lombardy poplar, plum, and cultivated cherry.

Ph. inversa. Prefers pin oak and red oak and sometimes is fairly

common on elm. It has also been taken on post oak, chinquapin oak, walnut, willow, hackberry, crataegus, and blackberry.

Ph. jonesi. Taken most commonly from persimmon and blackberry; also found feeding on hickory, oaks, walnut, crataegus, and elm.

Ph. kentuckiana. This species is very partial to pin and red oak. It has also been taken on hickory, bur oak, and elderberry.

Ph. micans. Prefers persimmon and oaks. It has been collected from pin oak, willow oak, red oak, post oak, white oak, persimmon, ash, plum, black gum, walnut, dogwood, mock orange, elderberry, and blackberry.

Ph. pearliae. This species has not been collected by the writer. According to Davis (1920) a number of individuals were found near Louisville on walnut and honey locust.

Ph. perlonga. Found feeding on ash and hickory.

Ph. pratermissa. Exhibits strong feeding preferences for oaks and willows; collected from pin oak, Spanish oak, post oak, willow, elm, ash, and hard maple.

Ph. profunda. Prefers oaks and blackberry; found feeding on willow oak, Spanish oak, red oak, post oak, blackberry, elm, and persimmon.

Ph. prunina. Collected from pin oak, Spanish oak, red oak, post oak, persimmon, winged elm, hickory, and blackberry.

Ph. quercus. Found feeding only on oak. One specimen was found on willow oak and a pair was found on an unidentified oak.

Ph. rugosa. A very general feeder exhibiting some preferences for pin oak, birch, sycamore, and elm. This species was also found feeding on post oak, plum, locust, walnut, willow, Lombardy poplar, mock orange, and blackberry.

Ph. tristis. Exhibits a very strong preference for oaks, principally pin, red, bur, and chinquapin; also found on willow oak, Spanish oak, post oak, white oak, elm, blackberry, and maple.

Ph. vehemens. One male was collected from walnut.

The trees and shrubs occurring in the state may be divided into groups based on the attractiveness of their foliage for May beetles and the susceptibility of these hosts to stripping (table 11). The trees most often fed on are certain species of oak, persimmon, hickory, walnut, elm, and birch. Foliage damage to these species is apt to occur in regions where trees are relatively scarce and where

there are large expanses of sodland in which white grubs may develop. When planting isolated trees in farming areas where May beetles are abundant these facts should be kept in mind. Such precautions are not necessary in the city where May beetles and their grubs are usually scarce.

Reaction to Lights. For many years it has been known that May beetles are strongly attracted to lights. In olden times, it was suggested that fires be lighted to destroy May beetles flying into them and later lanterns were suspended over tubs of water. More recently, with the development of electricity, electric lights of various sorts have been used to attract the beetles. Today, most workers consider lights of small value in May-beetle control since Sanders and Fracker (1916) and others found that mostly males were captured. However, many have found lights a useful method of collecting May beetles for distribution studies.

Table 11. Relative attractiveness of trees and shrubs as food plants for May beetles.

Much preferred, sometimes stripped	Often fed on, never stripped		Rarely fed on	Never fed on
pin oak	Spanish oak	hackberry	mulberry	English oak
red oak	post oak	locust	maples	tulip tree
white oak	willow	fruit trees	box elder	holly
bur oak	plum	Lombardy poplar	beech	magnolias
chinquapin oak	ash	sassafras	wild cherry	evergreens
persimmon	sycamore	redbud	Osage orange	chestnut
hickory	crataegus	blackberry	sumac	ginkgo
walnut	black gum	rose	hibiscus	
elm			mock orange	
birch			dogwood	

The reaction of the various species of May beetles to lights was studied in three localities in or near Lexington in 1936, and in one locality near Lexington in 1939. Lights were operated at Princeton in 1937. A total of over 13,000 beetles were collected, identified and tabulated by date and type of light. Data on the catches by species and date of collection are given in tables 12-14*.

Taking the Lexington catches as a whole, over 86 percent of the May beetles caught were males and slightly less than 14 percent were females. In the case of *Ph. fusca*, however, more females were caught than males. A comparison of the Lexington light catches with

* Collections from two localities in Lexington, during 1936, are omitted because of the small number of beetles captured.

collections from food plants on approximately the same dates, indicates that *Ph. hornii* is very little attracted by lights.

At Princeton, 275 beetles belonging to eleven species were collected at lights in 1937. Seventy percent of these were males. *Ph. bipartita*, *Ph. implicita*, *Ph. arkansana*, and *Ph. hirticula* were strongly attracted to lights but *Ph. crenulata*, fairly common on nearby food plants during the last half of May, was represented in the total catch by only two specimens (table 14).

In the course of the study of lights, 13 comparisons were made between traps containing 60-watt, 100-watt, and 200-watt, white, frosted bulbs of the ordinary household type. The relative positions of the bulbs were varied since the center trap usually operates at a disadvantage compared to the end traps. It was found that, other factors being equal, the beetle catch varied with the brilliance of the bulb used (tables 15 and 16). Considering the current consumed, however, for ordinary collecting the 100-watt, white, frosted bulb is probably the most efficient.

Dr. C. O. Eddy, in 1935, concluded from his study of light traps

Table 12. May beetles collected in light traps at Hillenmeyer Nurseries, Lexington, 1936.

Species	Sex	May 6	7	8	12	15	19	Total by sexes	Totals
<i>Ph. hirticula</i>	males	219	2,905	2,875	1,257	72	295	7,623	8,203
	females	14	203	255	49	19	40	580	
<i>Ph. inversa</i>	males	12	15	82	3			112	130
	females	1	6	9	1		1	18	
<i>Ph. futilis</i>	males	12	4	23	2		1	42	81
	females	8		26	4		1	39	
<i>Ph. tristis</i>	males	15	11	22	1	1		50	65
	females	4	5	6				15	
<i>Ph. rugosa</i>	males			5	9		6	20	23
	females			1	2			3	
<i>Ph. fusca</i>	males			2				2	15
	females		5	5	3			13	
<i>Ph. bipartita</i>	males	1		3				4	4
	females								
Totals		286	3,154	3,314	1,331	92	344	8,521	

at this Station that traps are most attractive when placed at the base of a favored food plant. He also found that the lamp should be hung low over the tub of water and backed by a shield of galvanized iron (figure 23). Traps of this general type were responsible for the catches reported in tables 12, 13, and 16.

Table 13. May beetles collected in light traps at Hillenmeyer Nurseries, Lexington, 1939.

Species	Sex	May 5	8	9	10	11	17	17	24	June 5	15	Totals
<i>h. hirticula</i>	males	43	458	62	1,243	3	87	299	357	166	26	2,744
	females	10	195	6	158	12	19	208	133	30	14	785
<i>h. inversa</i>	males	27	14	3	14	2	1					61
	females	4	3		4			3		1		15
<i>h. futilis</i>	males	11	9	5	27	47	2	5	3	3		112
	females	4	10	2	5	1	4	4	6			36
<i>h. tristis</i>	males	14	47	5				5	4			75
	females	1	6	1				1	3			12
<i>h. fusca</i>	males	3	4	1				1				9
	females		2		2	2		3				9
<i>h. rugosa</i>	males		2		4		4	4	14	1		29
	females				1			4	4			9
<i>h. bipartita</i>	males		1		1	1		1	3			7
	females				1				6			7
<i>h. hornii</i>	males											0
	females								2	1		3
Totals		117	751	85	1,460	68	117	538	535	202	40	3,913

Mating. May beetles mate at night on the leaves of the various food plants. On warm nights, much of the buzzing sound in the vicinity of favorite hosts is made by males seeking females which are feeding quietly on the leaves. Mating of the various species occurs in approximately the order of their flight periods. In the Inner Bluegrass, *Ph. tristis* is one of the first to mate. In 1939, two pairs of this species were found mating on May 5 at 7:14 p. m. Mating pairs of *Ph. tristis* were common on May 9. On the same date, the first mating pair of *Ph. hirticula* was found and by May 17 mating pairs of this species were common. Some mating of *Ph.*

Table 14. May beetles collected at lights, Princeton, 1937.

Species	Sex	April 22	May 8	12	21	June 1	Totals
Ph. praetermissa	males	1					1
	females	1		3	1		5
Ph. fervida	males		1	2	2		5
	females			1			1
Ph. bipartita	males		11	48	44	12	115
	females		1	6	11	3	21
Ph. implicita	males			2	34	5	41
	females				29	3	32
Ph. hirticula	males			1		1	2
	females			6	8	1	15
Ph. arkansana	males			8	14	1	23
	females			1	3		4
Ph. ilicis	males			2			2
	females						0
Ph. prunina	males			1			1
	females			1			1
Ph. crenulata	males			1			1
	females				1		1
Ph. profunda	males			1		1	2
	females			1			1
Ph. micans	males						0
	females					1	1
Totals		2	13	85	147	28	275

Table 15. Catch of May beetles in light traps of different brilliance, Princeton, 1937.

Date of observation	60-watt white frosted bulb		100-watt white frosted bulb		200-watt white frosted bulb		Totals
	Number of beetles		Number of beetles		Number of beetles		
	Males	Females	Males	Females	Males	Females	
May 8	4	0	6	1	2	0	13
May 12	13	4	15	4	24	9	69
May 21	15	6	16	11	38	29	115
June 1	5	1	5	3	3	3	20
Sum	37	11	42	19	67	41	217
Totals	48		61		108		

hirticula was observed as late as June 15. No mating of *Ph. hornii* was found until May 24.

Egg Laying. Cage experiments with *Ph. futilis*, *Ph. inversa*, *Ph. bipartita*, and *Ph. hornii* show that May beetles begin laying eggs 9 to 10 days after mating. At Lexington in 1939, *Ph. tristis* had begun laying eggs by May 10. Eggs of this species were laid as late as May 29. *Ph. hirticula*, the dominant Inner Bluegrass species, be-



FIGURE 23. Type of light trap used for collecting May beetles. Photo by Vaughn.

gan laying the last of May, 1939, and deposited eggs until late in June. *Ph. hornii* began oviposition early in June, in 1939, and the last eggs were laid the first part of July. *Ph. ephilida*, dominant Outer Bluegrass species, began laying about July 13 and eggs were deposited until late in August.

A single May beetle, on the average, deposits approximately 50 eggs (table 17). These are laid over a period of one to three weeks. Eggs are deposited by the female in the soil at depths of 3 to 7 inches. As many as 9 eggs are laid in a single "nest" and each egg

is found in the central cavity of a small ball of dirt, held together by secretions of the female (figure 20).

Table 16. Catch of May beetles in light traps of different brilliance, Lexington, 1939.

Date of observation	60-watt white frosted bulb		100-watt white frosted bulb		200-watt white frosted bulb		Totals
	Number of beetles		Number of beetles		Number of beetles		
	Males	Females	Males	Females	Males	Females	
May 5	37	2	17	6	44	11	117
May 8	91	30	157	83	287	103	751
May 9	11	1	37	4	28	4	85
May 10	242	36	489	31	558	104	1460
May 11	24	7	18	7	11	1	68
May 16	43	10	15	10	36	3	117
May 17	42	33	112	58	161	132	538
May 24	72	40	151	39	158	75	535
June 5	32	7	103	14	35	11	202
June 15	5	2	10	5	11	7	40
Totals	599	168	1109	257	1329	451	3,913
Percent by sexes	78	22	81	19	74	26	

THE EGG STAGE

When first laid, May beetle eggs are pearly white and oblong (figure 24). After a week or so the eggs increase in size and become almost round (figure 25). Twenty freshly laid eggs of *Ph. hirticula*

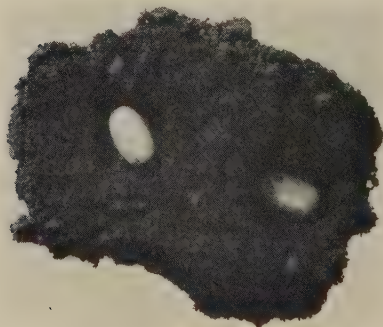


FIGURE 24. Freshly laid eggs of *Ph. hornii*, x 2½.

an average-sized May beetle, averaged 2.38 mm. long and 1.49 mm. wide. Ten 10-day-old eggs of *Ph. hirticula* averaged 2.96 mm. in length and 2.45 mm. in width. Measurements of the eggs of this and several other species of May beetles are given in table 18.

Eggs of *Ph. tristis*, under conditions approximating those in the field, hatch in 15 to 21 days, with an average period of 18 days. Eggs of *Ph. hirticula* hatch in 20 to 25 days. The length of the egg stage for these and 15 other species of May beetles is given in table 19.

Table 17. Egg capacity of several species of May beetles.

Species	Number of females	Mean number of eggs per female
<i>Ph. futilis</i>	3	29
<i>Ph. inversa</i>	5	55.2
<i>Ph. bipartita</i>	5	38.4
<i>Ph. hirticula</i>	7	51
<i>Ph. hornii</i>	4	63.3
Mean number of eggs per female		48.5

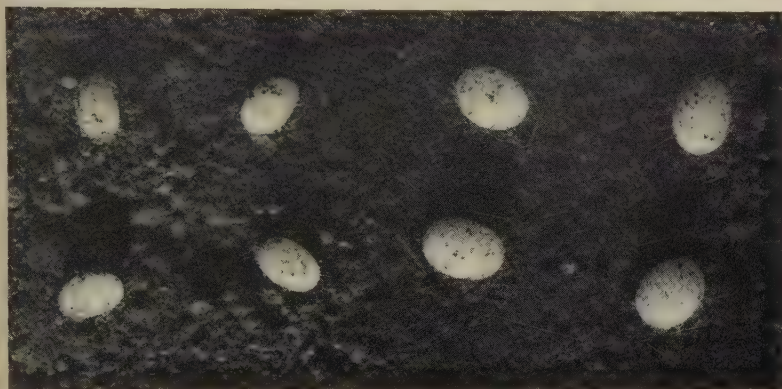


FIGURE 25. Freshly laid May beetle eggs on left; eggs ten days old on right, x 3.

Table 18. Size of May beetle eggs

Species	No. of eggs	Newly laid eggs						No. of eggs	Older eggs					
		Length in mm.		Width in mm.		Average			Length in mm.		Width in mm.		Average	
		Min.	Max.	Min.	Max.	l.	w.		Min.	Max.	Min.	Max.	l.	w.
<i>Articulata</i>	20	2.17	2.54	1.4	1.67	2.38	1.49	10	2.6	3.24	2.26	2.72	2.96	2.45
<i>partita</i>	7	2.15	2.45	1.46	1.55	2.33	1.51	10	2.72	3.35	2.28	2.51	2.89	2.35
<i>ornii</i>	10	2.4	2.8	1.5	1.9	2.62	1.64	10	3.0	3.4	2.4	2.7	3.17	2.59
<i>steri</i>	20	2.09	2.76	1.15	1.5	2.38	1.38	10	2.3	2.53	2.09	2.3	2.41	2.2
<i>ilis</i>	10	1.8	2.2	1.1	1.4	1.97	1.3	4	2.4	2.5	1.8	2.0	2.47	1.9
<i>hilida</i>	8	2.09	2.3	1.25	1.32	2.16	1.27	10	2.65	2.8	1.92	2.09	2.71	1.99

THE LARVAL STAGE

May beetle eggs hatch into small, white grubs (figure 26). The short interval of time from hatching until the first instar grub adjusts itself to feeding is a very critical one—one which many grubs do not survive if the soil is too wet, too dry, or too hot. Young grubs at first subsist on the organic matter of the soil but soon turn

their attention to the roots of growing plants. The roots of pasture grasses are the preferred food of most species.

Life in the Soil. During the first season of larval life, individuals of species such as *Ph. hirticula*, *Ph. hornii*, and *Ph. rugosa*, which commonly have a three-year life cycle, molt once and become second-instar larvae. This usually occurs in August. First-instar larvae of *Ph. tristis*, many first-instar larvae of *Ph. futilis*, and larvae of most other species having a two-year cycle, molt twice the first season of larval life and pass the winter as third-instar larvae. Larvae of *Ph. ephilida*, which has a two-year cycle but of a different type, begin hatching the last of July. Most first-stage larvae of this species become second-instar larvae before winter, while a few winter as first-stage larvae.

Table 19. Incubation period of May-beetle eggs, 1936-1939.

Species	No. of eggs	Min. no. of days	Max. no. of days	Mean no. of days
<i>Ph. hirticula</i>	53	20	25	23.3
<i>Ph. futilis</i>	41	21	29	22.9
<i>Ph. inversa</i>	21	23	25	24.7
<i>Ph. hornii</i>	75	21	29	23.6
<i>Ph. tristis</i>	54	15	21	18.1
<i>Ph. fusca</i>	5	24	24	24
<i>Ph. bipartita</i>	57	19	23	21.1
<i>Ph. forsteri</i>	70	21	24	22.8
<i>Ph. delata</i>	12	20	22	21.7
<i>Ph. implicita</i>	38	18	21	19.2
<i>Ph. micans</i>	16	19	21	19.2
<i>Ph. prunina</i>	5	20	23	22.4
<i>Ph. crenulata</i>	6	21	21	21
<i>Ph. fervida</i>	8	22	24	23.5
<i>Ph. praetermissa</i>	2	22	28	25
<i>Ph. fraterna</i>	10	22	26	25.1
<i>Ph. ephilida</i>	51	15	20	18.4

By the middle of October, 1937 and 1939, most second-instar grubs in the vicinity of Lexington had burrowed downward in the soil to seek winter quarters. During the winter of 1937-38, 62 second-stage larvae belonging to several species were dug from bluegrass pasture on the Station farm at Lexington. These were found at depths ranging from 4.5 to 11 inches, with an average depth of 7.8 inches. Nine of the 62 grubs were found at or above the plow line. During the winter of 1939-40, 50 second-stage *Ph. hirticula* grubs were dug on the Station farm at an average depth of 8.4

inches with a range of 4 to 12 inches. Thirty, second-instar, *Ph. hirticula* grubs dug from a pasture northeast of Lexington were found between 4 and 10.5 inches with an average depth of 7.1 inches.



FIGURE 26. Eggs and newly hatched larvae of *Ph. futilis*, x 5.

Grubs that pass the winter as second-instar larvae are much slower in leaving winter quarters than are third-instar grubs. Second-instar grubs do not become active again until April. In 1938, even on April 11, many second-instar grubs were still in their winter quarters. In 1940, the great majority of second-instar grubs were still in their winter cells on April 16.

It is during the second year of larval life that grubs feed ravenously on the roots of bluegrass and other plants and cause the most damage. Early in June, second-instar grubs molt and become third-instar grubs (figure 27). Third-instar grubs continue feeding and by fall are practically full grown. Late in August some burrow downward in the soil to seek winter quarters. Others continue feeding until late in October before going into hibernation. It is thought that many of these latter are third-instar grubs of individuals having a two-year cycle.

During the winter of 1937-38, 28 third-instar grubs, including a number of *Ph. futilis* grubs, were found at an average depth of 9.5 inches in a bluegrass pasture on the Station farm. The range was from 3.5 to 14.5 inches and 3 were found at or above the plow line. During the winter of 1938-39, 30 third-instar *Ph. hirticula* grubs were dug in a bluegrass pasture northeast of Lexington at an average depth of 13.7 inches. Depth of hibernation ranged from 9 to 19.5 inches.

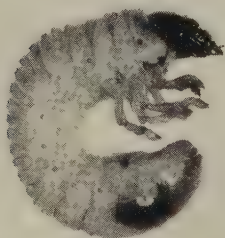


FIGURE 27. Third-instar larva of *Ph. hirticula*, x $1\frac{1}{2}$.

The same winter, 15 third-instar grubs of *Ph. ephilida* were dug from winter quarters in a pasture at Kingston. Their average depth was only 3.2 inches with a range of 3 to 4 inches. On March 26, 1939, about five hundred third-instar and a number of second-instar *Ph. ephilida* grubs were collected behind the plow in Clark county west of Winchester. Most, if not all of these, were still in their winter cells. It is concluded from this

evidence and that secured in other diggings that grubs of *Ph. ephilida* winter above the plow line.

In the vicinity of Lexington third-instar larvae begin to leave winter quarters late in March. By April 10 most of them are close to the surface. On April 8, 1938, many third-instar larvae of *Ph. hirticula* and several of *Ph. fusca*, *Ph. inversa*, and *Ph. futilis* were found beneath sod. On March 22, 1939, near Versailles, no May beetle grubs were found beneath 125 square yards of sod. This was in a pasture known to be heavily infested with grubs. On April 4, 1939, the first third-instar larvae of *Ph. hirticula* were found near the surface. This was in a bluegrass pasture north of Lexington where workmen were stripping several hundred feet of sod.

Third-instar grubs of such species as *Ph. hirticula* feed near the surface the latter part of April and during May. Early in June, they move downward in the soil where they construct more or less horizontal cells. As will be pointed out in the discussion of pupation, the species vary widely as to the depths at which pupation oc-

curs. After constructing their pupal cells, the larvae cease feeding and lie outstretched and motionless for a period of a week or more. Then they are said to be in the prepupal stage.

Food Preferences of White Grubs. Openings or clearing in woodlands were probably the original homes of many species of white grubs. In areas where such conditions prevail today, grubs of a number of species are commonly found. With the clearing of the land and planting to large acreages of a single crop, certain species have increased greatly in numbers. Thus in the pasture lands of the Inner Bluegrass, *Ph. hirticula* is now dominant. Other species of May beetles which are often abundant in pasture land in other parts of Kentucky include *Ph. ephilida*, *Ph. crenulata*, *Ph. bipartita*, *Ph. inversa*, *Ph. micans*, and *Ph. fraterna*.

Certain crops such as tobacco, sweet clover, and alfalfa seem to be relatively free of grubs. However, grubs of all sizes have been found abundantly in lespedeza sods. Corn is also subject to attack.

Much has been written about grubs as pests of strawberries but few records have ever been published in which the species responsible were accurately determined. During the past four years, a number of grubs have been dug that were in the act of feeding on berry plants. It was possible to identify some of these at once and others were reared to the adult stage for identification. It is concluded that *Ph. ephilida* is responsible for much of the damage to strawberries in western Kentucky. Other species of grubs found attacking berry plants in western Kentucky are *Ph. crenulata*, *Ph. micans*, *Ph. hirticula*, *Ph. profunda*, *Ph. arkansana*, *Ph. prunina*, and *Ph. praetermissa*.

Species of grubs found attacking berry plants in the Inner Bluegrass are *Ph. hornii*, *Ph. rugosa*, *Ph. futilis*, *Ph. hirticula*, and *Ph. inversa*. *Ph. hirticula*, so abundant in the Inner Bluegrass, infrequently attacks strawberries and such damage as occurs is usually the work of other less common species. In 1938 the writer raised a patch of berries on ground heavily infested with *Ph. hirticula* grubs and lost not a single plant on account of grubs.

White grubs injure grasses and corn by chewing off the roots. Often injured sod can be rolled up like a carpet. Corn injured by grubs is stunted and yellow. Grubs injure strawberries by gnawing into the crowns or cutting off the roots (figure 28). Frequently adjacent plants are killed by the same grub.



FIGURE 28. Strawberry plants killed by white grubs, showing typical injury.

The Species of White Grubs. The genus *Phyllophaga* is one of several genera making up the family Scarabaeidae. According to Hayes (1929), the family may be divided into two broad groups. One, called the *Laparosticti*, which includes mostly dung-feeding forms, is characterized in the larval stage by the galea and lacinia of each maxilla not being fused. The other group, called the *Pleurosticti*, includes mostly "leaf chafers" and is characterized in the larval stage by the galea and lacinia of each maxilla being fused. The *Pleurosticti* are further divided into the subfamilies *Cetoniinae*, *Rutelinae*, *Dynastinae*, and *Melolonthinae*.

Common Kentucky species belonging to the *Cetoniinae* are *Cotinis nitida*, the green June beetle, and several species of *Euphoria* called bumble flower beetles. The larvae of all these crawl on their backs. Common Kentucky *Rutelinae* are several species of *Anomala* and *Pelidnota punctata*, the six-spotted grape beetle. Common Kentucky *Dynastinae* are *Ligyrus gibbosus*, the carrot beetle, and *Cyclocephala immaculata* and *borealis*, the annual May beetles.

The May beetles (Phyllophaga) belong to the subfamily Melolonthinae. White grubs belonging to the genus *Phyllophaga* usually may be recognized by the following characters: the labrum is asymmetrical; the mandibles bear no oval, stridulating area of transverse striae on their caudal aspect; a series of lateral striae and usually a series of submarginal striae (proplegmata of Boving) are found on the inner surface of the labrum; the ventral surface of the last abdominal segment usually bears a double longitudinal row of spines; and the anal slit is angulate.

Much of the pioneer work in this country in the study of distinguishing the genera and species of grubs was done by Forbes (1891) and especially Hayes (1928 and 1929). The most important contributions to our knowledge of the species of May beetle grubs at the present time are being made by Boving of the U. S. Bureau of Entomology and Plant Quarantine. Boving published a preliminary key to 43 species of *Phyllophaga* in 1937 and is working now on an improved key for these and many other North American species. In the course of his study, Boving has discovered a number of mandibular and maxillary characters which make possible for the first time positive identifications of many species of grubs. In 1939, in a paper entitled "Descriptions of the three larval instars of the Japanese beetle, *Popillia japonica* Newm." he pointed out the value of mandibular characters in the following words (p. 186-187): "In the larvae of many Scarabaeidae, for instance, in those of the *Phyllophaga*, some characteristic features are seen on the dorsal surface of the mandibles, such as patches of minute hairs or groups of sac-bearing punctures ("sensilla ampullacea") which have proved to be of value for specific determination and also differ in the various instars."

The writer began his studies of white grubs in 1932 at the University of Wisconsin and learned to distinguish between a few of the species occurring there. Since 1936, he has reared grubs of many species from eggs laid by identified and isolated females. Use has also been made of molt skins of a number of reared species and of skins found associated with adults in pupal cells. As a result, at the present time, the writer possesses numerous specimens of the grubs of 26 Kentucky species of *Phyllophaga*. Based on this collection, a field key to 14 species was published early in 1938.

During the past two years, Boving has allowed the writer access

to his manuscripts on white grubs and the writer has furnished Boving with many reared grubs including several species not represented in Boving's collection. The writer, profiting from this exchange, has improved his own key and now is able to make positive identification of many of the white grubs found in the State. This knowledge has been of great help in studying the biologies of the Kentucky species. Since Boving's keys to the species of Phyllophaga will not appear in print in final form for some time, the writer wishes to stress the fact again that the value of certain characters used in the key here presented was first pointed out by Boving. This applies especially to characters found in the dorso-exterior region of the mandibles and on the articulating skin of the maxillae (figure 30).

Many of the structures mentioned in the key can be examined with a binocular microscope on living or dead grubs without dissection. The epipharynx can be examined without harm to living grubs by using a dissecting needle to turn back the labrum. Sometimes the number of setae and punctures on the dorso-exterior region of the mandibles can be made out without dissection. It is more satisfactory, however, if the mandible is mounted on a slide and examined with the low power of a compound microscope. The structures mentioned in the key are illustrated in figures 29 and 30.

The writer makes no pretense that the key presented is perfect. Because of the variation found even in the characters of a given species, occasional grubs may not key to the correct species. Too, since the species ranges are made fairly broad, grubs of species not included in the key will, of course, key incorrectly. In two cases, the writer was not able to separate two species of grubs.

Key to Kentucky White Grubs

1. Spines in radular rows sparsely set; majority of spines separated at their bases by a distance greater than the width of a spine at its base; radular spines often more or less blade-like (compressed) and hooked at tips (figure 29, B1 and B2)2
- Spines in radular rows closely set; spines depressed or conical; tips never hook-like (figure 29, C1)11

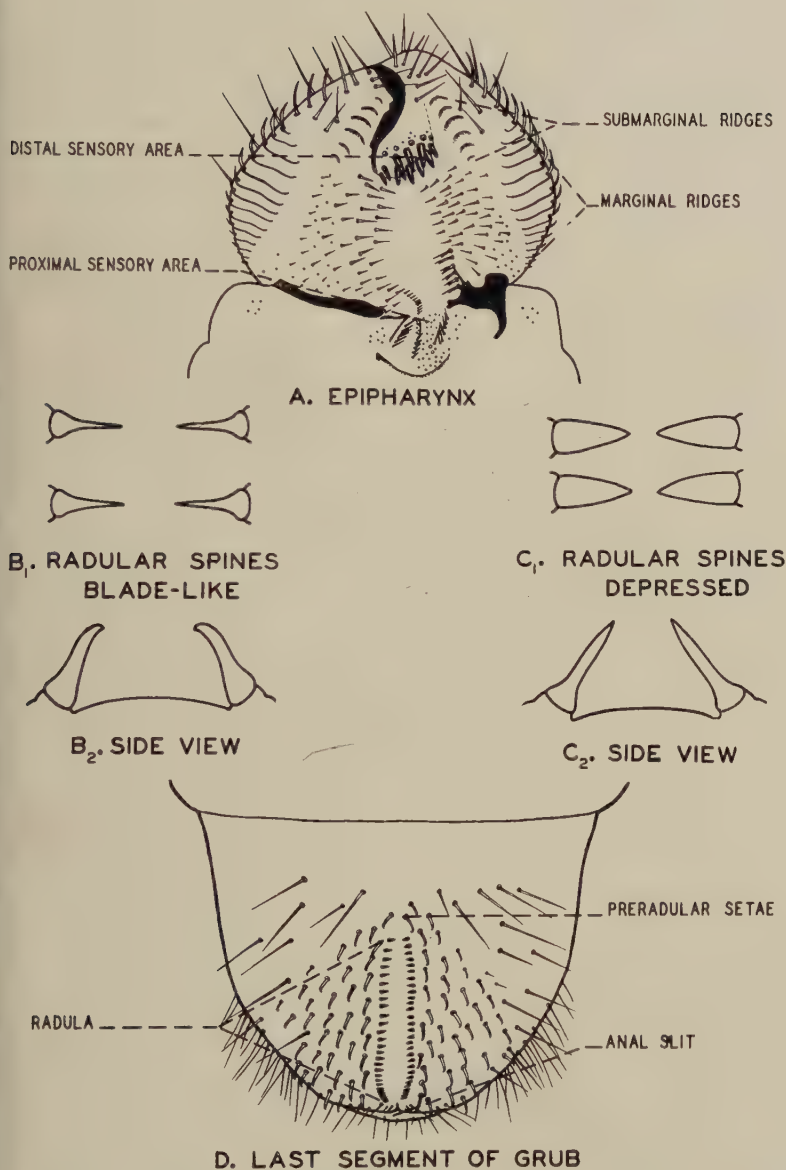


FIGURE 29. A. Epipharynx of white grub (*Phyllophaga* sp.). B₁ and B₂. Blade-like radular spines (compressed). C₁ and C₂. Depressed radular spines. D. Last segment of a *Ph. hirticula*, third instar grub, ventral view.

2. Submarginal ridges absent on epipharynx 3
 Submarginal ridges present on epipharynx (figure 29 A) 4
3. Articulating skin of maxilla bears only setae on its ventral surface (figure 30 C). Rows of 10-13 short, rather conical radular spines curved to form a wide oval **Ph. tristis**
 Articulating skin of maxilla bears 9 to 17 conical sensilla on its ventral surface (figure 30 D). Radular rows of 10-12 short, hooked spines nearly parallel **Ph. quercus**
4. Thirteen or fewer radular spines in each row 5
 Fourteen or more radular spines in each row 6
5. Two to four broad submarginal ridges on each side; 6 to 10 radular spines in each row; none to three preradular setae **Ph. praetermissa**
 Five or six indistinct, narrow submarginal ridges on each side; 9 to 13 radular spines in each row; three or more preradular setae **Ph. implicita**
6. Submarginal ridges curved, usually well developed and 5 to more than 10 on each side 7
 Submarginal ridges not curved, often indistinct, may be absent on right side 9
7. Radular spines not distinctly blade-like but tips turn in; preradular setae usually absent; 7-9 submarginal ridges; head of third instar larva less than 4.5 mm across **Ph. ephilida**
 Radular spines distinctly blade-like; preradular setae numerous; head of third instar larva over 5 mm across 8
8. Punctures usually absent on dorso-exterior region of mandible; radular spines fairly short, majority separated at tips by a distance greater than the length of a spine **Ph. fusca**
 Dorso-exterior region of mandible bears 3 or more punctures **Ph. anxia**

9. Submarginal ridges fairly well developed on both sides,
ridges short **Ph. fervida**
Submarginal ridges poorly developed, may be absent on
one side 10
10. Fewer than 18 radular spines in each row **Ph. arkansana**
More than 20 radular spines in each row **Ph. inversa**

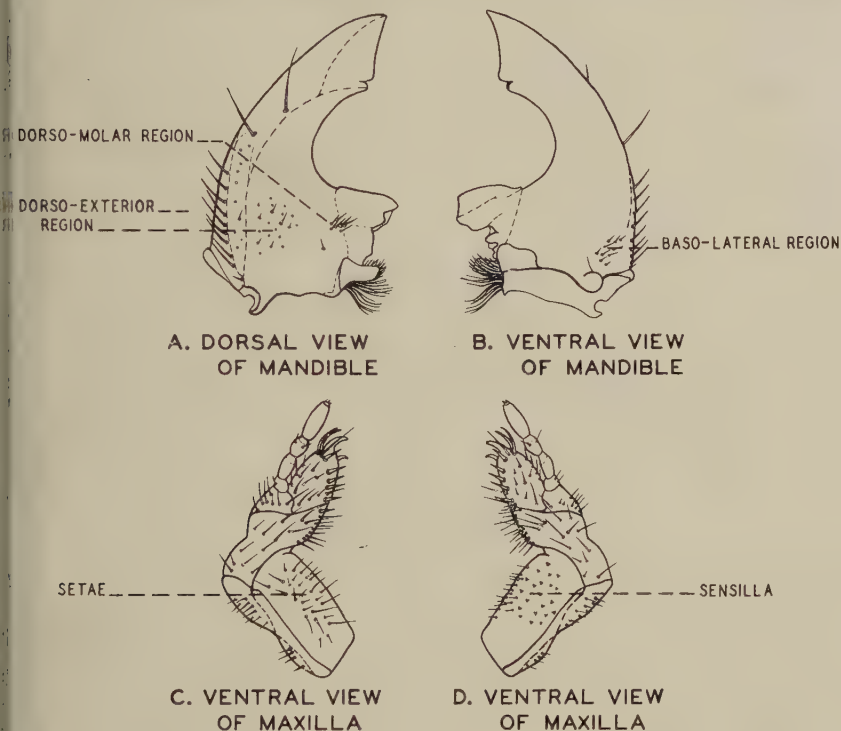


FIGURE 30. A. Dorsal view of the mandible of a *Ph. hornii*, third instar grub. B. Ventral view of the mandible of a *Ph. hornii*, third instar grub. C. Ventral view of the maxilla of a *Ph. prunina* grub. D. Ventral view of the maxilla of a *Ph. crenulata* grub.

11. Epipharynx bears fewer than 11 submarginal ridges on
each side 12
Epipharynx bears more than 11 submarginal ridges on
each side 20
12. Three to 4 small, short, submarginal ridges . **Ph. micans**
Four to 10 curved submarginal ridges on each side 13

13. Radular spines very long and sharp, at least four times as long as the width of their bases; 8 to 10 narrow submarginal ridges on each side **Ph. futilis***
 Radular spines, not over three times as long as the widths of their bases 14
14. Dorso-exterior region of mandible with fewer than 4 setae 15
 Dorso-exterior region of mandible with from 5 to more than 15 setae (figure 30A) 17
15. Six (rarely seven) submarginal ridges on each side; radular spines fairly long, close set, 22 to 31 in number **Ph. bipartita**
 Seven or more submarginal ridges on each side; radular spines rather short 16
16. Baso-lateral region of mandible bears 10 or fewer setae; greatest width of head capsule of third instar larva less than 4.7 mm **Ph. fraterna**
 Baso-lateral region of mandible bears 12 or more (12-15) setae; head capsule of third instar larva at least 4.8 mm wide **Ph. hirticula**
17. Submarginal ridges fairly short, usually fewer than 9 in number; ridges in center of row not over 4 times as long as wide; head capsule of third instar larva less than 4.9 mm wide **Ph. kentuckiana** and **Ph. delata**
 Submarginal ridges long, narrow and strongly curved, 8 to 11 in number; ridges in center of row at least 6 times as long as wide; head capsule of third instar usually 5 mm or more in width 18
18. Dorso-exterior region of mandible with fewer than 10 setae and not over 20 setae and punctures all together (figure 30 A) **Ph. hornii**
 Dorso-exterior region of mandible with 15 or more setae 19

* The writer possesses one third instar cast skin of *Ph. balia* which has similar characters.

19. Dorso-exterior region of mandible usually bears 35 or fewer setae and punctures, at least two-thirds of the total number are setae; head capsule of third instar larva 6 mm or more in width **Ph. profunda**
 Dorso-exterior region of mandible usually bears 40 or more setae and punctures, less than half of the total number are setae; head capsule of third instar larva less than 5.5 mm wide. **Ph. rugosa**
20. Maxillary articulating skin with short, conical sensilla on ventral surface (figure 30 D); usually 22 or fewer radular spines **Ph. crenulata**
 Maxillary articulating skin with long and short setae on ventral surface (figure 30 C); 23-27 radular spines 21
21. Submarginal ridges 11-15 in number; radular spines fairly long **Ph. prunina**
 Twenty or more submarginal ridges; radular spines short **Ph. corrosa**

MAY-BEETLE PUPATION

Time of Pupation. The time of year that May-beetle grubs pupate varies both with the species and with the season. At Lexington, in 1936, *Ph. futilis* grubs began pupating the last of July. Pupae began transforming to adults the third week in August and some transformed as late as the first week in September. No observations on the pupation of other species were made in the field that year.

In 1938, at Lexington, the first pupa of *Ph. hirticula* was found July 4 and by July 21 most of the *Ph. hirticula* grubs had pupated. The first newly transformed adult of *Ph. hirticula* was found July 31. By August 15 most of the *Ph. hirticula* pupae transformed to adults and only adults were found in pupal cells after August 23. Two adults of *Ph. futilis* were found in pupal cells on the same date. In 1939, *Ph. hirticula* pupation was a week to 10 days later than in 1938. Pupation began about July 10 and the first newly transformed adult was found August 8. No *Ph. hirticula* pupae were found after September 1.

Several observations were made in 1939 on the pupation of *Ph. inversa* (figure 31). Grubs of *Ph. inversa* apparently began pupating in 1939 the last of July and the first pupae to transform to adults

did so about August 25. Of a total of 13 *Ph. inversa* dug from pupal cells on the Station farm August 29 one was an adult and 12 were still pupae. Most of these transformed to adult beetles by September 3.

In 1939, special attention was given to a study of the time of pupation of *Ph. ephilida*. Pupation began shortly after June 1 and by June 7 almost all the *Ph. ephilida* found in pupal cells were pupae. The first newly transformed adult was dug June 22. Most of the *Ph. ephilida* pupae had transformed to adults by June 26.



FIGURE 31. Pupa of *Ph. inversa* in pupal cell, x 1½

Length of Pupal Stage. Records on the length of the pupal stage were obtained for a total of 113 grubs. These were for grubs allowed to pupate and transform to the adult stage in a basement during the summers of 1936, 1938, and 1939 (table 20). The temperature in this basement was fairly constant, ranging from 71 to 76° F. in the course of the three seasons. This approximates average soil temperatures at Lexington during July and August at depths ranging from 4 to 36 inches. (Fitten and Brooks, 1931.)

Of the 14 species of grubs under observation, *Ph. ephilida* had

the shortest pupal stage, averaging 19.5 days. The pupal stage of *Ph. hirticula* required 25 to 29 days, with a mean duration of 27.2

Table 20. Length of pupal stage of several species of Phyllophaga.

Species	Number of individuals	Length of pupal stage in days		
		Minimum	Maximum	Mean
<i>Ph. hirticula</i>	26	25	29	27.2
<i>Ph. ephilida</i>	17	17	20	19.5
<i>Ph. fusca</i>	15	27	30	28
<i>Ph. futilis</i>	12	23	27	24.8
<i>Ph. inversa</i>	11	24	28	26.9
<i>Ph. micans</i>	11	23	27	25.2
<i>Ph. bipartita</i>	10	26	28	27.1
<i>Ph. arkansana</i>	3	29	31	30.3
<i>Ph. fervida</i>	2	25	26	25.5
<i>Ph. fraterna</i>	2	25	26	25.5
<i>Ph. corrossa</i>	1	27	27	27
<i>Ph. balia</i>	1	26	26	26
<i>Ph. rugosa</i>	1	29	29	29
<i>Ph. hornii</i>	1	32	32	32

days. The mean number of days required for the pupal periods of the other 12 species varied from 24.8 to 32 days.

Depths of Pupation. Data on the pupation depths of several species of Phyllophaga were gathered in 1936, 1938, and 1939 (tables 21, 22, and 23). Each individual record is based on the finding of a prepupa or pupa which was reared to the adult stage or on the locating of larval and pupal exuviae after an adult was found. All records where only the adult was located have been omitted. Except in Area C, which will be mentioned later, practically every digging was made to the depth of at least 24 inches.

Areas Sampled. Area A was fallow ground with a cover of annual grasses, ragweed, and smartweed. The soil type was Hagerstown silt loam* which is one of the fertile soils of the Inner Bluegrass and similar to the Maury silt loams in structure. The area sampled was about half-way up an east slope in rolling country two miles southwest of Lexington.

Area B was in a permanent bluegrass pasture. The soil type was Maury silt loam which is the most important and fertile soil of the Inner Bluegrass. The area sampled was high, well-drained bottom land five miles northeast of Lexington.

*The writer is indebted to Martin E. Weeks for the identification of soil types.

Area C was bluegrass pasture on the Experiment Station Farm at Lexington. The soil type was Maury silt loam. Most of the diggings were made on high ground.

Area D was woodland, wild-grass pasture near Minorsville in Scott county, in the hill region that surrounds the Inner Bluegrass. Much of this area is poorly drained. Certain samples were dug in Eden clay while others were dug in heavy silt loam underlaid by Eden clay. Most of the beetles were obtained from the lower parts of the hillsides. Few were found on the higher, more rugged slopes.

Area E was Outer Bluegrass sod land near Louisville. Some of the diggings were made on high ground while others were in a well-drained lowland bordering a small creek.

Area F was an Outer Bluegrass pasture between Richmond and Berea. Beetles were obtained from the higher parts of a fairly steep east slope.

Species Preferences. *Ph. hirticula* larvae, regardless of soil type, almost always pupate several inches below the plow line, if the plow line is assumed to be six inches (table 21). The mean depths of pupation for this species in four areas ranged from 12.3 to 15.6 inches. Of the 191 individuals dug, the shallowest pupated at 7 and the deepest at 23 inches. On the basis of a small number of records, it is concluded that *Ph. rugosa*, a species closely related to *Ph. hirticula*, has similar habits, usually pupating several inches below the plow line.

In contrast, larvae of *Ph. inversa* pupated at shallow depths even in the same samples where *Ph. hirticula* grubs pupated deep in the soil. The mean depths of pupation for 51 *Ph. inversa* grubs ranged from 4.5 to 6.9 inches. Many *Ph. inversa* larvae pupated above the plow line, especially in heavy soil. *Ph. ephilida* is another species with the habit of pupating at shallow depths. The mean depth of 77 pupation sites was only 3.3 inches.

There is a third group of May-beetle species which ordinarily pupates at intermediate depths. In this group the writer places *Ph. futilis*, *Ph. bipartita*, *Ph. fusca*, *Ph. fraterna* and *Ph. tristis*. Some larvae of *Ph. futilis* pupate above the plow line as found in Area C; others pupate fairly deep. Grubs of *Ph. bipartita* usually pupated deeper than did larvae of *Ph. inversa* even in the same samples. Only 4 out of 48 individuals of *Ph. bipartita* pupated

Table 21. Pupation depths of *Ph. hirticula*, *Ph. inversa*, and *Ph. biparvita*.

Area	Locality	Ph. hirticula			Ph. inversa			Ph. bipartita					
		No. found	Depth in inches		No. found	Depth in inches		No. found	Depth in inches				
			Min.	Max.		Min.	Max.		Min.	Max.			
A	Lexington	118	7.5	23	15.6	5	5	8	6.6	1	7	7	7
	B Lexington	44	7	18.5	13.3	4	5.5	8.5	6.9				
	C Lexington	27	8	19	12.3	19	2.5	6.5	4.5	2	5	6	5.5
	D Minorsville	2	10	17.5	13.8	23	3	7.5	4.7	48	3	12.5	8

Table 22. Pupation depths of *ph. fulvis*, *ph. fraterna*, and *Ph. rugosa*.

[illegible]

*Almost all of these records for *Ph. futilis* in Area C were obtained in 1936. The writer found later that the soil had not been examined to a sufficient depth.

Table 23. Pupation depths of *Ph. fusca*, *Ph. ephilida*, and *Ph. tristic*.

Area	Locality	Ph. fusca			Ph. ephialda			Ph. tristis			
		No. found	Depth in inches		No. found	Depth in inches		No. found	Depth in inches		
			Min.	Max.		Min.	Max.		Min.	Max.	
A	Lexington	5	7.5	9.5	8.4			2	8	13.5	10.8
B	Lexington	1	9	9	9	53	2	6			
C	Lexington	4	4	9	7						
D	Minorsville										
F	Kingston					24	2.5	4.5	2	5	5.5
											5.3

at or above the plow line. Likewise, larvae of *Ph. fusca* and *Ph. fraterna* seldom pupated above the plow line.

A few records were obtained for 5 other species of Phyllophaga which are not included in the tables. Two pupation sites of *Ph. ferivida* were found in western Kentucky at 3 and 4 inches, respectively. Two pupation sites of *Ph. arkansana* were found at 4 and 6 inches. One pupation site of *Ph. micans* was found at 5 inches, one pupation site of *Ph. crenulata* was found between 12 and 15 inches, and one pupation site of *Ph. kentuckiana* was found at 9 inches.

WHITE GRUBS OTHER THAN PHYLLOPHAGA

The Cyclocephalas. White grubs belonging to the genus *Cyclocephala* are commonly found in sod land associated with May-beetle grubs (figure 32). *Cyclocephala* grubs are often abundant, also, in moist soil close to straw stacks and manure piles, situations where May-beetle grubs are rarely found.*

Two species of *Cyclocephala* are commonly found in Kentucky. The first, *Cyclocephala immaculata* Oliv. is widely distributed over the state. It is especially abundant in the Inner Bluegrass and often equals in number all the species of May-beetle grubs put together. The second species, *Cyclocephala borealis* Arrow (formerly *villosa*), is rare in the vicinity of Lexington but is common in Kenton county. The two species may be distinguished in the adult stage by differences in the male genitalia (figure 33) and by the fact that the elytra of *C. borealis*, in the male, bear numerous hairs.

The amount of damage caused by the *Cyclocephalas* in the state is not known. *C. immaculata* is found in city and other lawns. Areas where much of the sod was destroyed by it, have been seen. *Cyclocephala* grubs also are frequently abundant in tobacco land and land planted to small grains. According to Hayes (1918 and 1925) the larvae are often injurious to the roots of staple crops. He found them very abundant in wheat and rather abundant in corn and oats. Davis (1916) states that *Cyclocephala immaculata* may make full growth on decaying matter alone or may become a serious

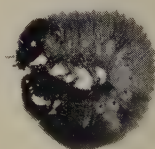


FIGURE 32. Third instar grub of *Cyclocephala immaculata*, x 1½.

* *Cyclocephala* larvae may be distinguished from May-beetle larvae by their transverse anal slit and the absence of a radula on the ventral surface of the last abdominal segment.

field pest similar to the May-beetle grubs. Neiswander (1938) found the larvae of *C. borealis* causing severe injury to lawns at many points in Ohio.

Life History. The writer has done little work with *C. borealis* so will confine his remarks to *C. immaculata*. This species, without

question, has a one-year cycle. The adult beetles emerge from the soil in June and July, mate and lay eggs. First-stage larvae hatch in two weeks and by fall have molted twice and become third-stage grubs. These winter in the soil, feed for a while in the spring, then pupate and transform to beetles in May and June.

In the vicinity of Lexington, *C. immaculata* adults first appear on the wing early in June. In 1936, the first adult was captured June 7; in 1939, the first adults were taken June 14. Drouth may delay the emer-

gence of beetles. This was true in 1936 when many remained in their pupal cells thruout June, unable to penetrate the hard soil above. In average years, heavy flights of *C. immaculata* take place during the last two weeks in June and the first two weeks in July. Occasionally adults are found on the wing until early in August.

C. immaculata adults begin flying in the evening while it is still quite light. On June 4, 1939, for example, flight began at 6:55 p. m. Adults are heard first buzzing in the grass as they seek a vantage point from which to take flight. They then take wing and skim about at a height of about one foot from the ground.

Adults of *Cyclocephala immaculata* and *borealis* are strongly attracted by lights. Altho usually many more males are caught than females, in some collections as high as 32 percent were females. Most beetles are caught between 7:30 and 9 p. m.

No mention is made in the literature of the food plants of adult

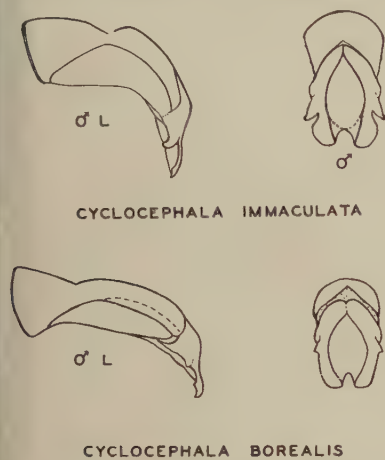


FIGURE 33. Male genitalia of *Cyclocephala immaculata* and male genitalia of *C. borealis*. A lateral view and a caudal view are shown for each species.

Cyclocephalas nor has the writer ever observed any feeding. On several occasions in 1936 and 1939 the writer secured many fertile eggs from reared adults kept in cans or tiles of soil, without food. From this evidence, it is concluded that *C. immaculata* adults probably do not feed.

Mating normally occurs at night on the surface of the soil. At 8 p. m. on July 12, 1936, for example, a buzzing sound in the grass enabled the observer to locate many mating pairs. Investigation in each case showed a mating pair surrounded by several males, all trying to mate with the same female.

Eggs are laid during the latter part of June and in July. They are deposited in the soil just below the sod mat. Freshly laid eggs are opaque white. Like May-beetle eggs, Cyclocephala eggs are oval when first laid but soon become almost round. The length of the egg stage is approximately 15 days.

C. immaculata grubs develop rapidly and by September 1 most of them are third-instar larvae. Cyclocephala grubs remain in the sod or close to the surface of the soil much later in the fall than do May-beetle grubs. In the vicinity of Lexington a few *C. immaculata* grubs begin moving down late in October and most of them are in winter quarters by the latter part of November. The depth at which *C. immaculata* grubs spend the winter is variable. In the same field their mean depths were 7.1, 5, and 10.4 inches, respectively, in the winters of 1936-37, 1937-38, and 1938-39. In this field, in 1937-38 only 7 out of 53 grubs were below the 6-inch plow line; in 1938-39 only 2 out of 44 grubs were above the 6-inch plow line.

C. immaculata grubs begin to move upward early in March and all are in the sod by the last of March in average seasons. In 1940 only a few *C. immaculata* grubs were in the sod by the last of March. The grubs stop feeding about the second week in May and move downward in the soil where they construct pupal cells at depths of 3 to 6.5 inches. The pupation depths of 73 individuals averaged 3.6 inches. A prepupal stage of 4 to 6 days precedes pupation which begins the latter part of May and continues into June. The length of the pupal stage varied from 14 to 20 days with a mean duration of 16 days for 15 individuals. Unlike May-beetle pupae, *C. immaculata* pupae lie inside the extended, third-instar exuviae. Pupae begin transforming to adults early in June.

The Anomalas. Four species of *Anomalas* were found in the course of the study of white grubs. These were *A. binotata* Gyll., *A. innuba* (Fab.), *A. nigropicta* Casey, and *A. flavipennis* Burm. (figure 34). Grubs of this genus were found in sod land in the same situations as May-beetle grubs.

Adults of *A. binotata* are in flight during May and are frequently attracted to lights. On May 9, 1939, 34 *A. binotata* adults were jarred from two pin oak trees near Lexington. According to department records, adults of this species were found gnawing holes in small apples on May 6, 1910, at Tip Top, Kentucky. Adults confined in the insectary laid eggs from May 12 to May 16, 1939. No larvae of this species were found in the field.

Adults of *A. nigropicta* are in flight during approximately the same period as *A. binotata*, being frequently collected at lights dur-

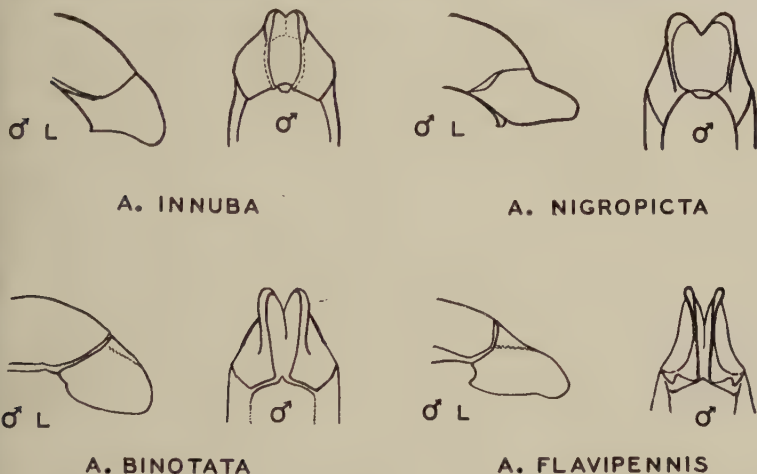


FIGURE 34. Male genitalia of *Anomala innuba*, *A. nigropicta*, *A. binotata*, and *A. flavipennis*. A lateral view and a ventral view are shown for each species.

ing May. In 1936, for example, 64 specimens were collected at lights near Lexington between May 5 and 12. Thirty-seven were males and 27 females. In 1939, 7 adults were caught in light traps on May 24. A few adults of *A. nigropicta* have been jarred from pin oak and on April 30, 1906, adults were found stripping leaves from a small cherry tree at Versailles.

A few larvae of *A. nigropicta* were dug from the soil in Lexington. One of these, dug August 23, 1938, became an adult September

13, in the laboratory. On August 31 of the same year two *Anomala* pupae were dug from the soil. One, found at 9 inches, had become an *A. nigropicta* adult when examined on September 13. Two adults of *A. nigropicta* were dug in the same area on October 13, 1938. It is concluded from these records that *A. nigropicta* pupates in the fall, the adults remaining in the soil until the following spring.

In contrast with *A. nigropicta*, individuals of *A. innuba* winter as full-grown larvae. Pupation occurs the following spring and the adults emerge in June. At Lexington, 7 *A. innuba* larvae were collected behind the plow, on February 17, 1938. Another larva was found 7 inches deep in the soil, on March 28, 1938. During the winter of 1938-39, 6 larvae of *A. innuba* were dug near Louisville. Their depths ranged from 6.5 to 9 inches with an average of 7.8 inches. Adults of *A. innuba* emerged at Lexington the latter part of June, in 1939. June 20, at 4:25 p. m., the writer collected 19 adults on the Station farm, which were feeding on the heads of timothy, in bloom at the time. June 21, one adult was collected at a light and on June 23 at 3:15 p. m. one adult was found feeding on timothy.

A. flavipennis appears to have a life history similar to that of *A. innuba*. Adults are in flight during June and were collected in some numbers at lights in Kenton county, in 1939, by H. Dorman and in Hart county, in 1934, by H. Elliott McClure. Adults were also collected at Lexington and Greenville. One full-grown larva of *A. flavipennis* was found in sod land in Lincoln county, March 21, 1939, behind the plow. October 12, 1939, 12 *Anomala* larvae were collected behind the plow in sod land in Allen county. From these 5 adults of *A. flavipennis* were reared.

The Green June Beetle, *Cotinis nitida* (L.). Green June beetles are familiar to everyone in the South. This is the species which flies in the daytime, skimming over the surface of lawns and golf greens. The beetles often cause considerable damage to ripening fruit such as apples, peaches, nectarines, blackberries and grapes. They also feed on tomatoes, corn in the milk stage, and draw sap from holes rasped in the twigs of pin oak and other trees. Green June-beetle adults are in flight during July and the first few days in August. In 1936, heavy flight began July 7 and continued thru July 31.

Green June-beetle grubs live in the soil where they feed on organic matter. They are particularly troublesome in lawns and on golf greens. They are seldom found in pasture land. Favorite breeding places for grubs are around manure piles, straw stacks, piles of grass clippings or in low, poorly drained soil. The larvae of the green June beetle can always be distinguished from May-beetle and Cyclocephala grubs by their queer habit of crawling on their backs with their feet up in the air (figure 35). Older green June-beetle grubs live in vertical tunnels in the soil which often extend to a depth of 15 or more inches. Rains or watering often cause many grubs to leave their burrows and crawl about over the surface of the soil. The grubs damage sod principally by disturbing the soil.

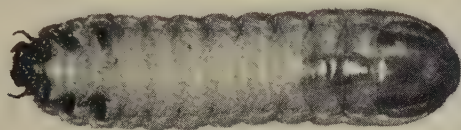


FIGURE 35. Third instar larva of the green June beetle in crawling position, x 1½.

NATURAL ENEMIES

White grubs are beset by natural enemies in all their life stages. Among their vertebrate enemies are toads, moles, skunks, hogs, fish, and many kinds of birds and man himself. There are also a number of invertebrate enemies including mites and many insect parasites and predators. Various fungi and bacteria also attack white grubs and in some years and localities have reached epidemic proportions, Davis (1919).

In the insectary, May-beetle eggs are frequently attacked by mites. Ants have also been known to destroy eggs. Common insect enemies of the grub stage in Kentucky are *Myzine quinquecincta* (Fab.) and several species of *Tiphia** and Asilidae (figure 36). Mites and fungi also attack grubs. Enemies of pupae include the larvae of a robber fly, *Diogmites discolor* Loew, and the larvae of a bee fly, *Exoprosopa fasciata* Macq. Adult May beetles are fre-

*Several *Tiphias* found parasitizing *Cyclocephala* and *Phyllophaga* larvae have been identified by Miss Sandhouse as *Tiphia intermedia* Malloch.

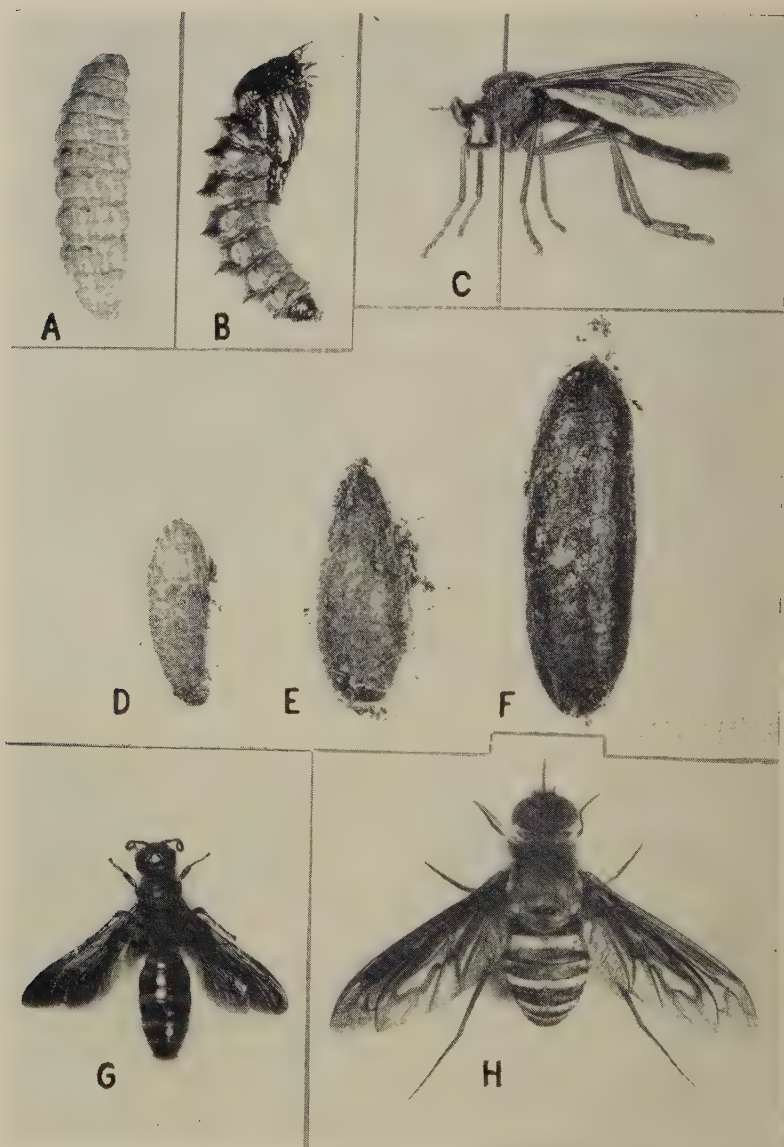


FIGURE 36. A, B and C (from left to right), full-grown larva, pupa and adult of *Diognites discolor*, x $1\frac{1}{2}$. D and E, cocoons of *Tiphia* spp., x $2\frac{1}{2}$. F and G, cocoon and adult of *Myzine quinquelineata*, x $1\frac{1}{2}$. H, adult of *Exoprosopa fasciata* Macq., x 2.

quently attacked by several species of flies which develop as maggots within the beetles' bodies. Among these are one or more species of *Pyrgota* and several *Sarcophagids*.*

Diogmites discolor Loew.** In 1938 and 1939, over 40 larvae of this asilid were found in the soil attacking *Phyllophaga* pupae or in pupal cells containing shriveled skins of *Phyllophaga* pupae. No evidence of this parasite attacking larvae was found. The pupae attacked belonged to the species *Ph. hirticula*, *Ph. fusca*, *Ph. inversa*, *Ph. rugosa*, and *Ph. tristis*. Pupal parasites were dug at Lexington, Kingston, Minorsville, and Buechel, Kentucky. At Lexington, in 1938, it is estimated that about 12 percent of the May-beetle pupae were destroyed by this one parasite.

Exoprosopa fasciata Macq. Three larvae of this bombyliid were dug from pupal cells of *Phyllophaga* at Minorsville, in Scott county, in 1938 and 1939. One of these had apparently attacked a larva or prepupa of *Ph. bipartita* and a second had attacked a pupa of *Ph. bipartita*.

METHODS OF STUDY

Many publications in recent years make little mention of the methods used in getting the results presented. The writer has found it of great help when starting a new project to know what methods were used by previous workers. Often, too, the reader has more criteria for judging the validity of the conclusions drawn if he knows by what means they were reached. For these reasons, the methods used in this study of white grubs will be discussed in some detail.

For the study of May beetle distribution, adults were collected from their food plants, at lights, behind the plow, from spider webs, by digging in the soil, behind men stripping sod, under sprayed trees, and as they emerged from the soil at night. A two-celled flashlight was most convenient for finding beetles on food plants. The signal lantern type was very handy and could be fastened to the belt. Often many May beetles could be secured from trees by having a boy climb and shake the tree or by simply jarring the trunk with the foot. In each area an attempt was made to collect May beetles from

* Hall in 1936 identified as *Sarcophaga rapax* Walk. adults of maggots parasitizing *C. immaculata* adults. He also identified *Sarcophaga l'herminieri* R. D. (?), reared from *Ph. hornii* adults.

** Identified as this species thru the courtesy of Stanley Bromley.

as many hosts as possible, and at different times during the flight season. Beetles were collected at many kinds of lights, such as light traps (figures 23 and 37), lighted windows, street lights, car lights and neon and argon signs. Ultra-violet, daylight blue and white frosted bulbs were employed as lures but the 100-watt, white, frosted bulb was as efficient as any of those tried.



FIGURE 37. Light trap set-up for the collection of May beetles.

An attempt was made to get beetles from as many counties as possible. Many nocturnal automobile trips were made involving numerous collections on the same night, in widely separated localities. Many collections were made by other members of the department and students. Use was made of the insect collections of the Covington Natural History Museum, the Western State Teachers' College, and the Department of Entomology and Botany of the University of Kentucky.

Captured May beetles were placed temporarily in salve boxes or jars labelled as to host and locality. At the laboratory each collection unit was tied in cheesecloth and preserved in 70 percent ethyl

alcohol. Later, as time was available, the material was identified and tabulated. Except sometimes in the case of *Ph. hirticula*, all identification was based on an examination of the genitalia.

Many distribution records were also made by collecting grubs behind the plow, by digging, or by picking up grubs where sod was being stripped. Some of these were identified in living or preserved condition; others were reared to the adult stage in two-ounce salve boxes of moist earth containing sprouting wheat.

In the study of the species of May beetles, the writer frequently had material identified or checked by other workers. He is indebted to Dr. Chapin of the National Museum, Dr. Philip Luginbill of the Federal Bureau of Entomology and Plant Quarantine, Dr. O. L. Cartwright of Clemson College, Dr. H. S. Reinhard of the Texas Agricultural Experiment Station, Dr. Milton Sanderson of the Arkansas Agricultural Experiment Station, Dr. William P. Hayes of the University of Illinois, and Dr. Adam Boving of the National Museum for these and other courtesies.



FIGURE 38. Cages used to get May-beetle eggs. Photo by Vaughn.

May-beetle eggs were obtained by confining mated females or copulating pairs in gallon tin cans half filled with packed, moist, sifted soil and supplied with a vial of foliage for food (figure 38).

Cans lacquered inside were preferred. The tops were capped with an oval piece of screen wire covered with cheesecloth and held in place by a rubber band. The cans were kept in a shaded insectary and the soil usually was sifted every two days.

The balls of soil containing eggs were broken and the eggs placed in individual cavities made in packed soil in a two-ounce salve box (figure 39). A cardboard scoop, about one and a half inches long

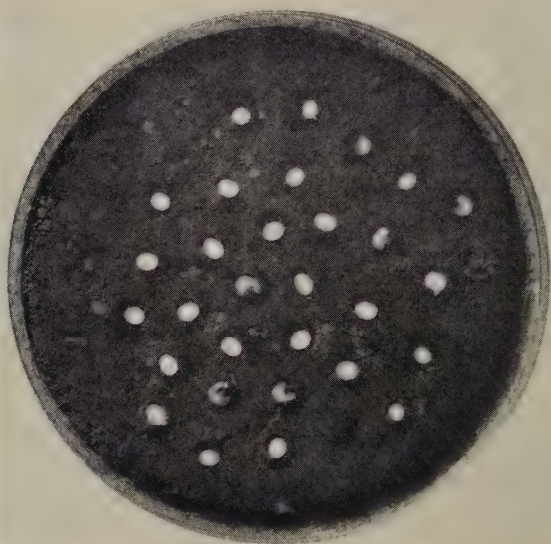


FIGURE 39. Showing method used in incubating May-beetle eggs. Natural size.

V-shaped in cross section, and pointed at the end, was used to handle eggs. Eggs were incubated in a cool basement. In order to have low mortality following hatching it was necessary to cover the eggs with moist, sifted soil when the mandibles of each larva began to show thru the chorion. This kept the newly hatched larvae from attacking one another and supplied them with food for several days.

First-stage larvae, about eight days after hatching, were transferred to two-ounce salve boxes containing wheat. To assure the lowest mortality, eight or ten kernels of wheat were placed in the bottom of the box. Next, the box was filled to overflowing with fresh, moist, sifted soil which was firmed with the hand. Following this, a probe was used to make a hole in the soil near one side of the

box, a small larva was dropped into the hole, and the box closed. Chamberlin, of the Federal White Grub Laboratory, found that by filling the salve boxes full in this manner the growth of molds was largely inhibited; the writer followed his method.

When it was desired that grubs be reared quickly, the salve boxes were kept at room temperature and the soil and wheat changed at two-week intervals. By the method outlined here, it was possible to produce third-instar grubs within sixty days after hatching.

Movements of white grubs in the soil, hibernation and pupation were studied mainly by means of samples dug in representative areas. When possible, samples were dug at weekly intervals. At any one time, a minimum of 1/10,000 acre was examined to a depth of 24 inches, in each area sampled. The sample was marked off with a sharp spade and the sod removed in four sections to a canvas where it was thoroly examined. Next, the soil was removed layer by layer using a trowel, and measurements were made *in situ* to the closest half inch. The spade was frequently used to remove thin slices of the lower layers.

Information on movement in the soil, hibernation and pupation was also obtained by collecting behind the plow or where sod was being stripped. In estimating grub populations in a given field, a minimum of eight, random, square-foot samples, six inches deep, were dug at times when grubs were near the surface. Hibernation and pupation studies were made easier by stocking screened areas with grubs collected behind the plow. Grubs so collected were placed either on top of the soil in the afternoon or in slits in the sod. The screened areas varied in size from 16 to 64 square feet.

Because of the length of time involved and the fact that much of the life cycle is spent underground, it is hard to make an accurate study of the normal life cycle of May beetles. Use was made of beetles and grubs isolated in screened boxes of soil, large flower pots, and tiles (figure 40). All three had many limitations and retarded development unless given careful attention. Of the three, the writer prefers ten-inch flower pots set in the soil and covered with screens during flight seasons.

To get data on the length of the egg stage, eggs of known age were kept in salve boxes of soil in a cool basement until hatched. To get data on the length of the pupal stage, prepupae were placed

in cavities in individual two-ounce salve boxes of moist soil and kept in the same basement. The dates of pupation and transformation to the adult stage were noted on the paper top of the box and later transferred to the permanent records, along with the species determination.



FIGURE 40. Tiles used in the study of May beetle and *Cyclocephala* life histories. Photo by Vaughn.

In the study of the species of white grubs, use was often made of larval exuviae from pupal cells or obtained by rearing grubs to the adult stage in the laboratory. The epipharynx, mandibles and radula were dissected and cleaned in distilled water under a binocular microscope and mounted in Liquid of Faure for study.*

Unless otherwise credited, the photographs used in this publication were made by the writer. When photographing larvae and pupae, use was made of a highly refined, volatile oil containing two percent free nicotine. This material quickly paralyzed the larvae or pupae and allowed them to be photographed with a minimum of distortion and discoloration.

* The formula for Liquid of Faure according to Chamberlin of the Federal White Grub Laboratory is as follows:

Distilled water	30 cc.
Gum arabic (finely granulated)	30 gms.
Glycerine	30 cc.
Cocaine	.5 gms.
Chloral hydrate	50 gms.

Dissolve the gum arabic in the distilled water; filter (both slow processes). Add glycerine and cocaine; when well mixed, dissolve in it the chloral hydrate.

SUMMARY

Studies of white grubs belonging principally to the genus *Phyllophaga*, show the group to be widespread over Kentucky and of great potential importance. Thirty-six species of *Phyllophaga* were found in the state. The genitalia of both males and females are illustrated for the purpose of identification. The presence and prevalence of the species of white grubs were found to vary with the physical regions of the state, many of these regions being characterized by the dominance of certain species. The distribution of many species is illustrated by individual maps.

Life history studies indicate that Kentucky white grubs have one-, two-, two- and three-, or three-year life cycles. The life cycles of *Ph. hirticula*, usually a three-year species, and *Ph. ephilida*, a two-year species, are charted. A detailed account is given of the hibernation of May beetles and it is concluded that they spend at least the first part of the winter in their pupal cells, some species beginning to burrow toward the surface in January or February. A detailed account is given of the sequence of emergence, seasonal abundance, and feeding preferences of many species of May beetles for a number of the state's physical divisions. Most of the stripping of oaks in May, in the Inner Bluegrass, is done by *Ph. hirticula*, the dominant species in that region. A study of light traps showed the common 100-watt, white, frosted bulb to be a more efficient lure than similar 60- or 200-watt bulbs.

Individual May beetles were found to lay approximately 50 eggs which hatched in from 15 to 29 days, depending upon the species and the soil temperature. Details of larval life in the soil and food preferences are presented. *Ph. ephilida* was found to differ from most other grubs in its hibernation habits, overwintering only three inches deep in the soil. A key is included by means of which the larvae of 23 species of *Phyllophaga* may be distinguished. The time of pupation and the length of the pupal stage are discussed and evidence is presented to show that some species, such as *Ph. hirticula*, pupate deep in the soil while such species as *Ph. inversa* and *Ph. ephilida* pupate at shallow depths.

The life histories of *Cyclocephala immaculata*, *Anomala innuba*, *A. nigropicta*, and *A. flavipennis* are discussed and mention is made of *Cyclocephala borealis*, *Anomala binotata*, and *Cotinis nitida*. All these have one-year life cycles. A number of natural enemies were

found attacking white grubs in various stages of their life cycles. *Diognites discolor* Loew is recorded as a common parasite of May beetle pupae. The methods used in the course of this study are discussed in detail.

BIBLIOGRAPHY

- Averitt, S. D. 1915. The soils of Kentucky. Ky. Agr. Exp. Sta. Bul. 193: 127-164.
- Bondurant, J. H. 1938. Factors for profitable farming on limestone hill land of the Eden formation in Kentucky. Ky. Agr. Exp. Sta. Bul. 384: 226-246.
- Boving, A. G. 1921. The larva of *Popillia japonica* Newman and a closely related undetermined ruteline larva. A systematic and morphological study. Proc. Ent. Soc. Wash. 23: 51-62.
- Boving, A. G. 1936. Description of the larva of *Plectris aliena* Chapin and explanation of new terms applied to the epipharynx and raster. Proc. Ent. Soc. Wash. 38 (8):169-185.
- Boving, A. G. 1937. Keys to the larvae of four groups and 43 species of the genus Phyllophaga. U. S. D. A. Bureau of Ent. and P. Q. E-417.
- Boving, A. G. 1939. Description of the three larval instars of the Japanese beetle *Popillia japonica* Newm. (Coleoptera, Scarabaeidae). Proc. Ent. Soc. Wash. 41 (6):183-191.
- Chamberlin, T. R., C. L. Fluke, Lee Seaton, J. A. Callenbach, and P. O. Ritcher. 1938. Population and host preferences of June beetles in southern Wisconsin in 1935, 1936, and 1937. Insect Pest Survey Bul. 18, Supplement to No. 4:225-240.
- Chamberlin, T. R., C. L. Fluke, Lee Seaton, and J. A. Callenbach. 1939. Population and host preferences of June beetles in southern Wisconsin in 1938. Insect Pest Survey Bul. 10, Supplement to No. 3:103-109.
- Criddle, Norman. 1918. The habits and control of white grubs in Manitoba. Agr. Gazette of Canada 5 (5):449-454.
- Davis, J. J. 1916. A progress report of white grub investigations. Jour. Econ. Ent. 9:261-281.
- Davis, J. J. 1919. Contribution to a knowledge of the natural enemies of Phyllophaga. Ill. Nat. Hist. Survey. Bul. 13 (5):53-138.
- Davis, J. J. 1920. New species and varieties of Phyllophaga. Ill. Nat. Hist. Survey. Vol. 13. Art. 12:329-338.
- Fitten, Edith M. and C. F. Brooks. 1930. Soil temperatures in the United States. Monthly Weather Review 59:6-16.
- Fluke, C. L. and P. O. Ritcher, 1934. Essential factors in control of white grubs. Wis. Agr. Exp. Sta. Bul. 428:97-100.
- Forbes, S. A. 1891. On the life history of white grubs. Insect Life 3 (5): 239-245.
- Forbes, S. A. 1916. A general survey of the May beetles (Phyllophaga) of Illinois. Ill. Agr. Sta. Bul. 186:215-257.
- Garman, H. 1913. The woody plants of Kentucky. Ky. Agr. Exp. Sta. Bul. 169: 1-62.
- Hayes, Wm. P. 1918. Studies on the life-history of two Kansas Scarabaeidae (Coleop.). Jour. Econ. Ent. 11 (1):136-144.
- Hayes, Wm. P. 1920. The life histories of some Kansas Lachnosterna. Jour. Econ. Ent. 13 (3):303-318.

- Hayes, Wm. P. 1925. A comparative study of the life-cycle of certain phytophagous Scarabaeid beetles. Kans. Agr. Exp. Sta. Tech. Bul. 16:146 pages.
- Hayes, Wm. P. 1928. The epipharynx of lamellicorn larvae (Coleop.) with a key to common genera. Ann. Ent. Soc. Amer. 21 (2):282-306.
- Hayes, Wm. P. 1929. Morphology, taxonomy, and biology of larval Scarabaeidae. Ill. Biological Monographs 12 (2):1-119.
- Johnston, H. R. and C. B. Eaton. 1939. White grubs in forest nurseries of the Carolinas. U. S. D. A. Bureau of Ent. and P. Q. E-486.
- Karraker, P. E. 1939. Soils, an elementary treatise. Ky. Agr. Exp. Sta. Extension Circular 54:1-63.
- Langston, J. M. 1927. Phyllophaga of Mississippi. Miss. Agr. Exp. Sta. Tech. Bul. 15:103 pages.
- Logan, W. S. 1939. A tentative key to Kentucky soils. U. S. D. A. Soil Conservation Service (Mimeogr.).
- Luginbill, Philip. 1928. The beetles of the genus Phyllophaga inhabiting South Carolina. Ann. Ent. Soc. Am. 21 (1):47-91.
- Luginbill, Philip. 1938. Control of common white grubs in cereal and forage crops. U. S. D. A. Farmers' Bul. 1798:19 pages.
- Meiswander, C. R. 1938. The annual white grub, *Ochrosidia villosa* Burm. in Ohio lawns. Jour. Econ. Ent. 31 (3):340-344.
- Roundstone, Bruce and W. J. Roth. 1935. Types of farming in Kentucky. Ky. Agr. Exp. Sta. Bul. 357:19-118.
- Hitcher, P. O. 1938. A field key to Kentucky white grubs. Jour. Kans. Ent. Soc. 11 (1):24-27.
- Hitcher, P. O. 1939. Observations on white grub pupation. Jour. Kans. Ent. Soc. 12 (2):64-69.
- Hitcher, P. O. and Fluke, C. L. 1935. Trees and the white grub menace. Jour. Forestry 33 (6):620-621.
- Sanders, J. G. and S. B. Fracker. 1916. Lachnosterna records in Wisconsin. Jour. Econ. Ent. 9 (2):253-261.
- Taylor, L. W. 1937. Revision of California Cyclocephala. Jour. of Ent. and Zool. 29 (3):67-70.
- Tom, R. J. 1928. Phyllophaga (Scarabaeidae) of the United States and Canada. New Jersey Dept. Agr. Circular 145:60 pages.
- Tom, Robt. J. 1934. Characters useful in distinguishing larvae of *Popillia japonica* and other introduced Scarabaeidae from native species. U. S. D. A. Circular 334:20 pages.
- Travis, B. V. 1934. Phyllophaga of Iowa. State College Jour. Science 8 (2):313-363.
- Travis, B. V. 1939. Migration and bionomics of white grubs in Iowa, 1930-35. Jour. Econ. Ent. 32 (5):693-697.
- Uliado, G. B. 1939. External anatomy and diagnostic characters of some common Philippine white grubs. Philippine Agriculturist 28 (5):339-410.

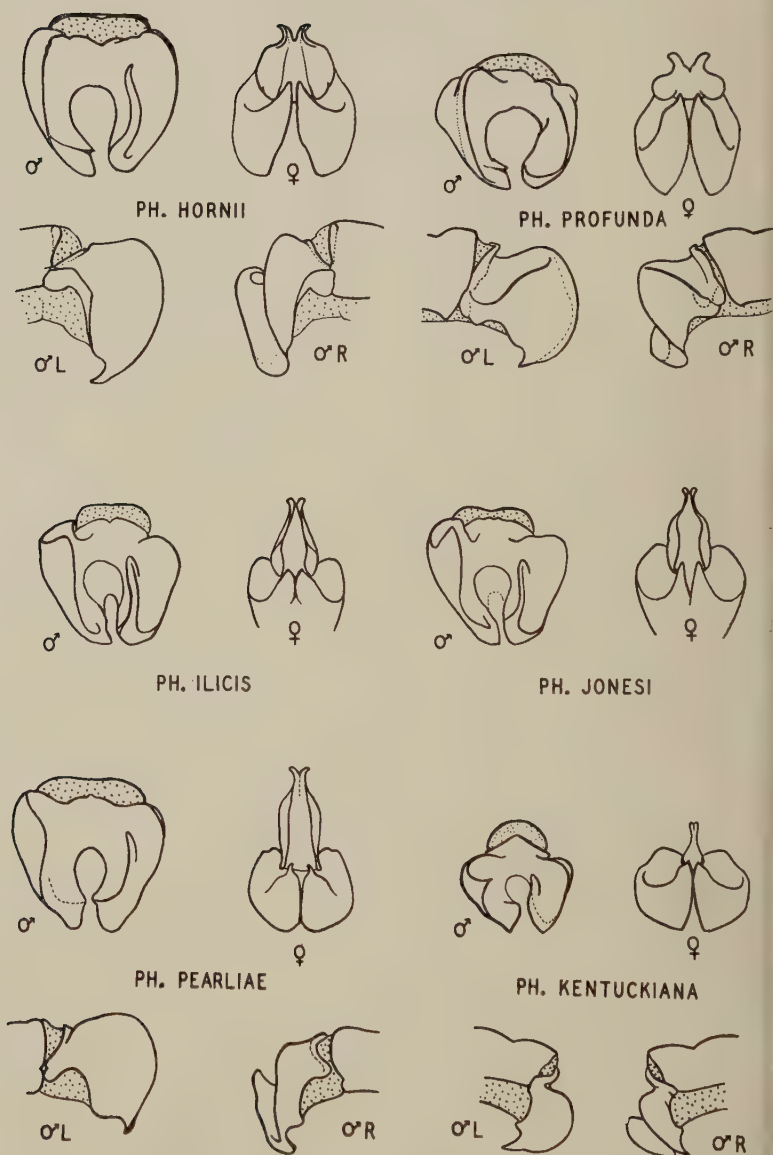
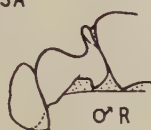
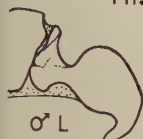


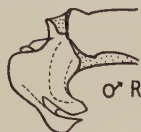
PLATE 1. Genitalia of *Ph. hornii*, *Ph. profunda*, *Ph. ilicis*, *Ph. jonesi*, *Ph. pearliae*, and *Ph. kentuckiana*. The genitalia of *Ph. pearliae* are redrawn from Davis (1920).



PH. RUGOSA



PH. INVERSA



PH. FRATERNA



PH. BIPARTITA



PH. HIRTICULA



PH. DELATA



PLATE 2. Genitalia of *Ph. rugosa*, *Ph. inversa*, *Ph. fraterna*, *Ph. bipartita*, *Ph. hirticula*, and *Ph. delata*.

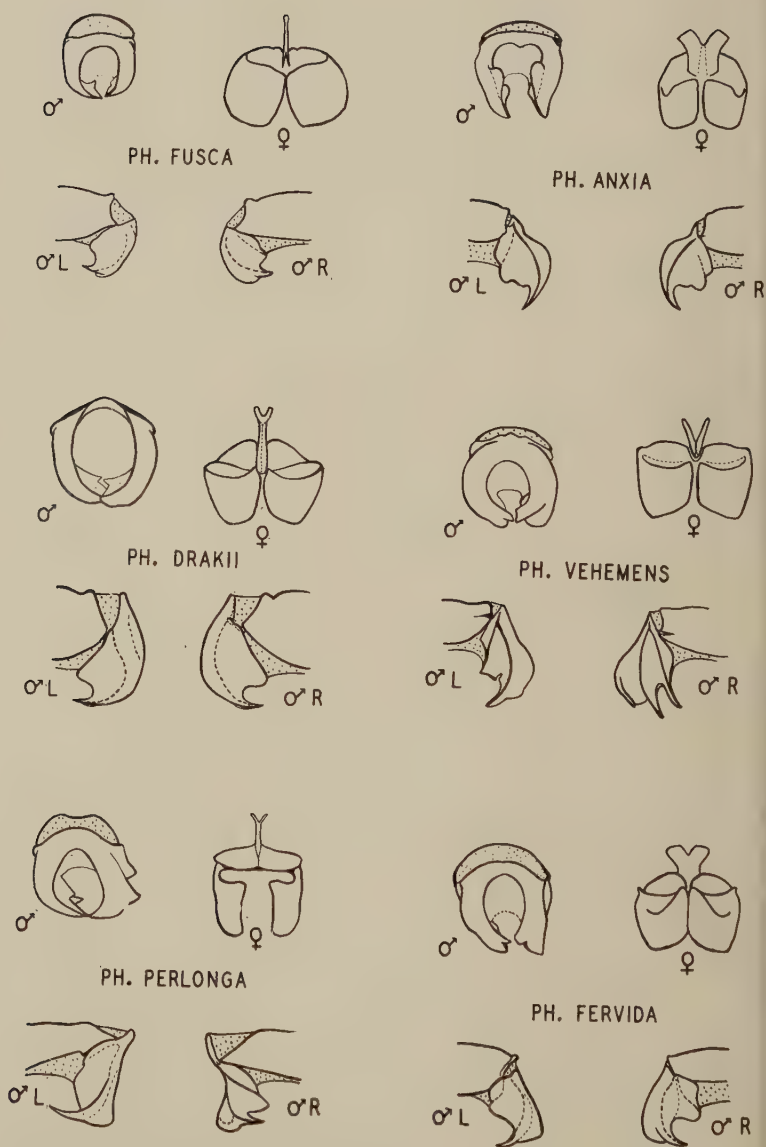
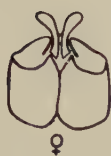
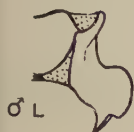


PLATE 3. Genitalia of *Ph. fusca*, *Ph. anxia*, *Ph. drakii*, *Ph. vehemens*, *Ph. perlonga* and *Ph. fervida*.



PH. PRUNINA

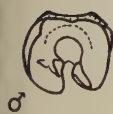
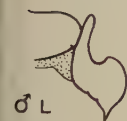
PH. ARKANSANA



PH. CORROSA



PH. BARDA



PH. BALIA



PH. VILIFRONS



PLATE 4. Genitalia of *Ph. prunina*, *Ph. arkansana*, *Ph. corrosa*, *Ph. barda*, *Ph. balia*, and *Ph. vilifrons*.



PH. FORSTERI



PH. PRAETERMISSA



PH. QUERCUS



PH. MICANS



PH. IMPLICITA



PH. GLABERRIMA



PLATE 5. Genitalia of *Ph. forsteri*, *Ph. praetermissa*, *Ph. quercus*, *Ph. micans*, *Ph. implicita*, and *Ph. glaberrima*. The female genitalia of *Ph. glaberrima* is redrawn from Sim (1934).



PH. EPHILIDA



PH. CONGRUA



PH. FUTILIS



PH. TRISTIS



PH. CRENULATA



PH. HIRTIVENTRIS



PLATE 6. Genitalia of *Ph. ephilida*, *Ph. congrua*, *Ph. futilis*, *Ph. tristis*, *Ph. crenulata*, *Ph. hirtiventris*. The female genitalia of *Ph. hirtiventris* is redrawn from Sim (1934).

Kentucky Agricultural Experiment Station

University of Kentucky

REPRODUCTIVE EFFICIENCY IN DAIRY CATTLE

BULLETIN NO. 402



Lexington, Kentucky

May, 1940

(159)

REPRODUCTIVE EFFICIENCY IN DAIRY CATTLE

By F. E. HULL, W. W. DIMOCK, FORDYCE ELY and
H. B. MORRISON

INTRODUCTION

The Kentucky Agricultural Experiment Station dairy herd was established in February, 1892, by the purchase of 2 Jersey cows. From 1893 to 1913, inclusive, 26 additional registered Jersey females were purchased. Crossbred animals were added in 1912, Holsteins in 1913 and Guernseys in 1919. The Guernseys were disposed of in 1934 and the crossbred animals in 1935. On December 31, 1939, this herd was composed of 32 Jerseys and 14 Holsteins, of breeding age, and 18 young heifers. Breeding records were kept from the beginning and are available in complete form as far back as January 1, 1900. Mr. John W. Nutter, the present superintendent of the herd, has been in charge since March 10, 1897, and to him the major credit is due for the accuracy and completeness of these early records.

From the time the herd was established until September, 1928, no systematic health program was followed. Bang's disease was probably introduced into the herd in 1898 or 1899. Three cows aborted in 1899. There were no recorded abortions previous to that year. One or more animals aborted in each succeeding calendar year up to and including 1939. *Brucella abortus* was first isolated from an aborted fetus from a cow in this herd by Professor E. S. Good on January 11, 1911.¹

The first test for tuberculosis was made in 1917. At this time 9 animals were found to be infected with this disease. The herd has been free from tuberculosis since 1920. The eradication of Bang's disease, which was started in September, 1928, was completed January 1, 1933.

¹ Good, E. S. Investigation of the Etiology of Infectious Abortion of Cows and Mares. Kentucky Agricultural Experiment Station Bulletin No. 165. 1912.

HEALTH PROGRAM

In September, 1928, a cooperative arrangement was made between the Dairy Department and the Department of Animal Pathology which provided for detailed supervision of the health and

HEALTH SHEET

Table 1.

DATES				REMARKS
Heat	Bred	Fresh	Vet. Diag.	
6/7/29				
6/30/29				
7/26/29				
8/18/29				
11/16/29				Too small to breed.
	3/9/30			Fairy's Oxford Observer.
		5/27/30		Pregnant.
		12/11/30		Heifer E 157. Weight 48 lbs.
1/21/31			1/7/31	Vaginal douche, clean.
	2/12/31			Remarkable Raleigh.
	3/13/31			Remarkable Raleigh.
		6/15/31		Pregnant.
		12/15/31		Heifer E 192. Weight 54 lbs.
1/27/32			2/17/32	Mastitis, right hind quarter.
	2/18/32			Fairy's Oxford Observer.
		4/22/32		Pregnant.
		11/23/32		Heifer E 218. Weight 54 lbs.
1/11/33				
	2/3/33			Hebron's Lord Raleigh.
		3/1/33		Mastitis. Sold for slaughter.
				Lifetime Reproductive Efficiency
				Calves born 3
				Total breeding months 39
				Months per calf 13
				Reproductive efficiency 92.3%

Animal No. E89

Animal's Name U.K. Jolly Frances

Sire Harmony's Golden Jolly 3rd

Breed Jersey

Dam Cocotte's Fawn Countess

Birth Date September 2, 1928

Disposal March 1, 1933

reproductive efficiency of the dairy herd. A more detailed method of keeping health and breeding records was begun at this time. Table 11 shows the form of record sheet used; and the data given constitute the actual record of a cow in the herd.

Since it appeared that *Brucella abortus* infection had been more or less prevalent in the herd since its foundation, the first step was the eradication of Bang's disease. The number and value of the reactors to the agglutination test for Bang's disease was such that it was thought best to use the following method of eradication. The cows were divided into two groups, reactors and non-reactors, which were kept on separate pastures but were stabled in the same barn. The reactors were sold for slaughter as soon as they ceased to be regular breeders and profitable producers. The non-reactors were divided into five units according to age and all were tested for Bang's disease before any animals were changed from one unit to another. The entire herd was tested at intervals of four months.

It was not possible to have separate bulls for the reactors and non-reactors to the test for Bang's disease. Cows and heifers were assigned to a certain bull and were not bred to another bull until they had given birth to a calf. The sheath of each bull was flushed with physiological saline at body temperature immediately following each service. No cows in the herd were bred sooner than sixty days after calving. Cows that aborted or had retained placenta were not bred until they were known to be in breeding condition.

In addition to the eradication of Bang's disease special attention was given to sterility, delayed conception, health of calves, mastitis, milk fever, acetonemia, nephritis, genital trichomoniasis and indigestion.

ANALYSIS OF REPRODUCTIVE EFFICIENCY

Since this herd has been in existence for 48 years and under the direction of the same superintendent for 43 years it furnishes excellent material for a study of reproductive efficiency in dairy cattle. This analysis covers the period from January 1, 1900, to December 31, 1939.

During the period under consideration 482 females of breeding age have been in the herd. Three breeds are represented: Jerseys from 1900 to 1939, Holsteins from 1913 to 1939 and Guern-

seys from 1919 to 1934. A few crossbred animals were in the herd from 1912 to 1935. Of the animals included in this analysis 438 were bred and raised on the farm and 48 were purchased. The last Jersey female was purchased in 1913; Holstein, 1923; Guernsey 1925, and crossbred animal in 1913. Complete breeding life records are available for 298 of the cows included in this study, while the records are incomplete for 184 animals. Cows with incomplete records are those that were in the herd prior to 1900, that were in the herd December 31, 1939, and those that were purchased, sold as breeders, or sent to other departments and substations. The distribution of these animals according to breed is shown in table 2.

Table 2. Number of females studied, by breeds.

	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
Total individuals	351	86	27	18	482
Number bred and raised on farm	323	77	22	12	434
Number purchased	28	9	5	6	48
Number of complete records	220	50	20	8	298
Number of incomplete records	131	36	7	10	184

Of the total number of animals considered in this study 72.8 percent were Jerseys; 17.9 percent Holsteins; 5.6 percent Guernsey, and 3.7 percent crossbred animals. Jerseys made up 100 percent of the herd for the first 12 years. During the time covered by this study the percentage of Jerseys, varied from 100 to 52.3, Holsteins from 39.7 to 5.1, Guernseys from 15.9 to 3.3 and crossbred animals from 16.3 to 1.5. The percentage distribution of the females of breeding age in the herd for the entire period by year and by breeds is shown in the appendix, table 9.

Breeders are not entirely in agreement regarding the age at which it is best to begin breeding heifers. In this study we have assumed that the Jersey, Guernsey and crossbred heifers were of breeding age at fifteen months and the Holstein heifers at eighteen months. In actual practice a few heifers were bred before and some were bred after they arrived at this arbitrary breeding age. Table 10 in the appendix shows the number of females of breeding age in the herd for the entire period of years and by breeds. In this table all females of breeding age that were in the herd as long as one month were counted. It should be noted that the time covered by this analysis is forty years. Jerseys were in the herd for

the entire period; Holsteins, twenty-seven years, Guernseys, sixteen years and crossbred animals twenty-four years.

Each calendar month after the heifer becomes of breeding age is called a breeding-cow month. If a heifer becomes of breeding age before the middle of the month that entire month is counted. Animals that become of breeding age after the middle of the month are not counted until the next month. A breeding-cow year is twelve breeding-cow months. Table 11 in the appendix shows the number of breeding-cow years for the herd, by years and by breeds, for the entire period. The difference between the actual number of animals as given in table 10 and the breeding-cow years as given in table 11 is caused by heifers becoming of breeding age and older animals being disposed of or dying during the year. By referring to tables 9, 10 and 11 the percentage distribution, total number of individuals and the breeding-cow years can be obtained for each breed and for the entire herd.

The time covered by this investigation is divided into three periods as far as Bang's disease is concerned. Abortion was a factor in this herd from 1899 to 1939. Bang's disease (*Brucella abortus* infection) was known to be a factor from January 11, 1911, to December 31, 1932. The eradication of Bang's disease covered a five-year period from 1928 to 1932. This herd has been free of this disease for seven years, 1933 to 1939.

Symptoms of genital trichomoniasis were first observed in the Kentucky Agricultural Experiment Station dairy herd in January, 1937. This disease was definitely diagnosed April 1, 1937. Eradication was completed December 31, 1938.

Table 11 in the appendix as well as several additional tables, give the total for the entire period studied, as well as subtotals for the different Bang's disease periods and the genital trichomoniasis period.

Income in the dairy industry is derived from the sale of milk, products made from milk, and the sale of animals for breeding purposes. The results of dairy-cattle breeding are measured in several different ways. Milk and butterfat production records, along with feed consumption records, aid in the selection of the more profitable animals. The Dairy Herd Improvement Association used milk and butterfat production records to prove dairy sires and to compute the transmitting index of bulls. Individuality,

as revealed by type and conformation, is used as a measuring stick at shows, fairs and in official classification of dairy herds. As a rule, general health, longevity and reproductive efficiency are not considered or are given secondary consideration.

Dairy cattle breeders have emphasized milk production for a given lactation, but have failed to emphasize the importance of reproductive efficiency over a period of years. A dairy cow may make a high production record during one lactation but a long interval between calves will result in a low lifetime milk-production record. Reproduction must precede milk production. Healthy animals are essential for high reproduction efficiency and longevity. The average dairy cow in the United States produces four or five calves in a lifetime and consequently produces milk for four or five lactations. Milk could be produced more economically if the reproduction efficiency of cows and heifers could be increased and the breeding life of the cows could be prolonged.

Reproductive efficiency has been computed by various investigators in many different ways as follows. 1. From the percentage of animals of breeding age that becomes pregnant. 2. From the percentage of animals actually bred that become pregnant. 3. From the percentage of pregnancies resulting in living calves. 4. From the number of services per pregnancy either including or excluding sterile animals. 5. From the interval between calves.

We did not follow any of these methods but adopted, with modifications, the method devised by Williams.² This method, with some modifications and additions, was used to measure the reproductive efficiency of the Kentucky Agricultural Experiment Station dairy herd. The reproductive efficiency of any number of animals for any number of months or years can be measured. In this study each calendar year was computed separately and in addition the weighted average for certain periods was obtained. One hundred percent reproductive efficiency means that each female of breeding age produced one calf for each twelve months that she was in the herd. Heifers were counted as in the breeding herd as soon as they reached breeding age (fifteen months for Jersey, Guernsey and crossbred heifers and eighteen months for Holstein heifers) altho they may not have been bred until later.

2. Williams, W. L. A standard for measuring the reproductive and dairying efficiency of cattle. *The Cornell Veterinarian* 9:204-213. 1919.

Cows were considered a part of the breeding herd until they died, were sold or transferred. Nine months of pregnancy was counted as equivalent to one calf. The difference between the number of months of pregnancy at the beginning of the time computed and at the end of that time was divided by nine. These were called potential calves and were added to or subtracted from the number of calves born. This method of measuring reproductive efficiency is illustrated in table 3.

Table 3. Reproductive efficiency of the Holsteins in the Experiment Station herd, in 1935.

Individuals	Condition and number of months pregnant. P=pregnant N=not pregnant		Date of birth	Months in the herd	Number of calves born	Remarks
	Jan. 1 or at time of entry into herd	Dec. 31 or at time of death or disposal				
E 113	P, 5	P, 5	8-12-29	12	1	-
E 131	N	N	1- 1-30	12	1	-
E 133	P, 2	P, 2	1-12-30	12	1	-
E 139	P, 7	P, 8	4-13-30	12	1	-
E 145	P, 4	P, 4	7-19-30	12	1	-
E 151	P, 1	P, 6	9-16-30	5	0	Sold 6-12-35
E 170	N	N	3-27-31	12	1	-
E 173	N	N	4-20-31	12	1	-
E 177	N	N	6-18-31	9	1	Died 9-30-35
E 182	N	N	7-13-31	12	1	-
E 206	P, 3	P, 3	5-24-32	12	1	-
E 220	P, 7	P, 8	11-28-32	12	1	-
E 235	P, 3	P, 3	5-26-33	12	1	-
E 252	N	N	9-23-33	9	0	Heifer
E 261	N	P, 4	12- 7-33	7	0	Heifer
15	P, 32	P, 43		162	12	

Months of pregnancy December 31, 43

Less months of pregnancy January 1, 32

Excess 11

Potential equivalent in calves ($11 \div 9$) 1.2

Calves born 12.0

Total calves, actual and potential 13.2

Total breeding months, 162

Number per calf ($162 \div 13.2$) 12.3

Reproductive efficiency of this group of Holsteins, in 1935, assuming that each heifer calved at 27 months and thereafter gave birth to one healthy calf

12×100

each 12 months, $\frac{\quad}{\quad} = 97.6$ percent.

12.3

The results of computing the reproductive efficiency of the Kentucky Agricultural Experiment Station dairy herd are tabulated in appendix, tables 12, 13, 14 and 15. Table 12 shows the number of breeding-cow months by years and by breeds and for the entire herd. The number of calves born and equivalent in pregnancies are given in table 13. This shows the actual reproduction of the herd. The loss or gain in existing pregnancies as well as the number of calves born are considered. Table 14 shows the calving interval or the number of breeding-cow months per calf. This was calculated by dividing the number of breeding-cow months, as given in table 12 by the number of calves born and equivalent in pregnancies, as given in table 13. The reproductive efficiency of the females of breeding age is given in table 15. This is calculated in percentage from the number of breeding-cow months per calf as given in table 14. A calving interval of 12 months was considered to be 100 percent reproductive efficiency. Tables 14 and 15 show the weighted averages for the entire period, for the different Bang's-disease periods and for the trichomoniasis period.

DISCUSSION

One of the essentials for successful agriculture is profitable livestock production. A successful livestock industry depends on good health and high reproductive efficiency of its breeding animals. The process of reproduction in mammals is very complex. This makes possible numerous causes of sterility and delayed conception.

Sterility, either temporary or permanent, may be defined as a failure of the reproductive system to function normally. Reproduction is a result of a series of actions coordinated with one another and requiring normal physiological processes in various organs and glands. If adverse conditions affect any part of the animal, reproduction may fail or be delayed. Reproductive upsets may have their influence on other physiological functions.

The cause of sterility and delayed conception may be found in any one of the following fields or in any combination of them; pathology, bacteriology, protozoology, endocrinology, genetics, nutrition, physiology and anatomy.

This analysis of the reproductive efficiency of the Kentucky Agricultural Experiment Station dairy herd shows considerable

variation, in efficiency from year to year. At times the trouble seems to be confined to a certain breed or age group or be due to a particular disease.

The majority of the domestic animals are bred at certain definite seasons of the year. It may be assumed that a uniform supply of milk during the entire year is desirable for the average dairy. Under such conditions, one-twelfth of the cows should calve each month; thus with 100 percent reproduction efficiency 25 percent of the females of breeding age should be pregnant from one to ninety days, 50 percent should be pregnant from ninety to two hundred-eighty days and 25 percent should have calved during the last three months. Since nature apparently intended the spring of the year to be the breeding season it is possible that the breeding of dairy cattle during the entire year accounts for a part of the poor reproductive efficiency.

In the past Bang's disease was the number one cause of breeding troubles in dairy cattle. Greatly improved reproductive efficiency usually followed the eradication of this disease. The weighted average of the number of breeding-cow months per calf for the Kentucky Agricultural Experiment Station dairy herd from the beginning until the eradication of Bang's disease was begun was 17.2. For the five years necessary for eradication of the disease the calving interval was 18.0 months. This increase in the calving interval was due to the large number of heifers that were kept to replace the cows that had Bang's disease. These heifers required more services for their first pregnancy than any other group of approximately the same number. At present we are unable to give a satisfactory explanation for this delay in conception.

From 1900 until January 1, 1933, when the eradication of Bang's disease was completed the calving interval was 17.4 months. For the first four years following the eradication of Bang's disease no serious breeding troubles were diagnosed. The calving interval for this period was 14.2 months for the entire herd. A herd of 100 cows with an interval between calves of 17.4 months would produce 69 calves per year, while 100 cows with an interval between calves of 14.2 months would produce 84.5 calves per year, a difference of 15.5 calves per year in favor of the Bang's disease free herd.

The introduction of genital trichomoniasis into the Holstein herd in January, 1937, resulted in an increase of 1.5 months in the calving interval for the herd as a whole, for the years 1937-1938 as compared with the previous four years. For these same periods the calving interval for the Jerseys decreased from 15.1 to 14.2 months. The calving interval for the Holsteins increased from 12.5 to 18.8 months.

The reproductive efficiency of the Holsteins was better than that of the Jerseys for each period except for the two years that genital trichomoniasis was in the Holstein herd and for 1939. The decrease in the calving interval of .9 month for the Jerseys during 1937-1939 as compared with the previous four years was probably due to improved breeding hygiene.

It may be that because of the increased milk production of the modern dairy cow it is too much to expect her to reproduce once each twelve months after she is of breeding age. Considering this herd as a whole the calving interval since Bang's disease eradication indicates that 14 to 15 months is all that can be expected. However, if the Holsteins for 1933-1936 are considered it may be that by a more careful selection of animals retained as breeders, a more detailed supervision of breeding hygiene and of the general health and nutrition of the herd, the ideal of the dairy cattle breeder, of a calf every 12 months, might more nearly be attained over a period of years.

Abortion is a frequent cause of low reproductive efficiency. Bang's disease, genital trichomoniasis and other known genital diseases are not the sole causes of abortion. On January 1, 1933, the Kentucky Agricultural Experiment Station dairy herd was considered to be free from all genital diseases except so-called granular vaginitis. During the last forty years 196, or 13.6 percent, of the 1438 known pregnancies resulted in observed abortions. For the first four years following the eradication of Bang's disease, the abortion rate for the entire herd was 9.3 percent, for the Jerseys, 11.8 percent and for the Holsteins, 3.7 percent. The introduction of genital trichomoniasis into the Holstein herd in January, 1937, increased their abortion rate for the next two years to 13.3 percent while abortions in the Jerseys dropped to 3.8 percent. Table shows the percentage of pregnancies that resulted in observed abor

tions, for the entire period as well as for the different Bang's disease and genital trichomoniasis periods. Table 16 in the appendix shows the number of abortions for the entire period by years and by breeds.

Table 4. Percentage of pregnancies that resulted in observed abortions, by breeds.

Years	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900-1939	14.6	10.0	14.1	10.9	13.6
1900-1932	16.0	11.7	13.3	11.3	15.1
1900-1927	16.7	11.3	13.5	10.7	15.6
1928-1932	12.1	12.5	13.0	16.6	12.4
1933-1936	11.8	3.7	25.0	0.0	9.3
1937-1938	3.8	13.3			7.3
1933-1938	9.1	7.1	25.0	0.0	8.6
1939	0.0	7.7*			2.6

Holsteins were in the herd, 1913-1939; Guernseys, 1919-1934; crossbreds, 1912-1935.

*This represents only one case classed as abortion out of a total of thirteen pregnancies. The calf was carried 235 days, was born alive, and lived 31 days.

The high percentage of abortions in the Guernseys after the eradication of Bang's disease is probably not significant. During this time the Guernsey herd was made up of three females that became pregnant a total of four times. One of these pregnancies resulted in an abortion.

No definite explanation for the high abortion rate in the Jerseys for 1933-1936 has been found. During this period 53 females that were sired by 5 different bulls became pregnant a total of 103 times. Twelve of these pregnancies resulted in abortions, one in a mummified fetus, 9 in calves born dead and 81 in calves born alive. The total pregnancies, abortions, calves born dead and calves born alive for the daughters of each of these 5 bulls are given in table 5.

The fetuses that were aborted were carried an average of 143.8 days. No female aborted more than once during this period. Seven of these were first pregnancies, 3 were second, one was third and one was fourth pregnancy. Eight of the twelve females that aborted conceived and produced live calves following the abortion. One of the aborting females had aborted once previous to 1933 but had produced live calves before aborting the second time.

Two daughters of bull F. O. O. each aborted their first pregnancy, had live calves the second pregnancy and their third pregnancies resulted in mummified fetuses. One of these mummified fetuses occurred after the 1933-1936 period.

Two daughters of bull F. O. O. each produced one agnathic male fetus. One of the fetuses was aborted and the other was obtained when the dam was slaughtered. A daughter of bull R. R. produced one agnathic male fetus after she was transferred to the Department of Animal Pathology. These three agnathic male fetuses³ were sired by bull R. E. G.

The calves born dead were carried an average of 279.3 days. Five of these calves were females and 4 were males. No cow had more than one calf born dead during this 4-year period. Of the 9 calves born dead 6 were first pregnancies, 2 were second and one was a fifth pregnancy. Dystocia definitely accounted for the fifth pregnancy calf being born dead. This dead calf was out of daughter of bull H.G.J. 3rd. Six of the remaining 8 calves that were born dead were out of daughters of bull R.R. and sired by bull F.O.O.

Bull R.R. sired 22 females that were raised to breeding age in the Kentucky Agricultural Experiment Station dairy herd. All of these females are dead except one eight-year-old cow. To date, these animals have been pregnant a total of 60 times. Thirty-six of these pregnancies resulted in calves born alive, 8 in calves born dead, 9 in abortions and in 7 cases the animal was sold or died while pregnant.

These daughters of bull R.R. had tubular genitalia that were smaller than that of the average Jersey female. The rectum and anus were also constricted in the majority of these animals. This constriction of the tubular genitalia, especially that of the vulva and cervix, made the first parturition very difficult. In 7 cases the vulva was so badly constricted that it had to be enlarged by making several incisions on each side between the dorsal and ventral commissures. Caesarian section was resorted to in one instance.

One of these females aborted the first pregnancy and was not bred again. Post-mortem examination showed a fibrous band 2 cm. wide and .5 cm. thick across the external orifice of the cervix. The kidneys were small, fibrous and contained numerous small calculi.

Seventeen of the 22 daughters of bull R.R. showed albuminuria on repeated urine examinations. Nine of these animals eventually

³ Ely, Fordyce; F. E. Hull, H. B. Morrison. Agnathia, a new bovine lethal. *Journal of Heredity* 30:104-108, 1939.

developed nephritis.⁴ Urinary calculi were found in all these cases.

Table 5. Breeding record of fifty-three daughters of five different Jersey bulls during the four years, 1933-1936.

Sire	Number of daughters	Pregnancies	Abortions	Calves born dead	Calves born alive
F.D.A.	3	3	0	0	3
H.G.J. 3rd	9	23	0	1	22
R.R.	19	49	6	6	28
F.O.O.	18	33*	6	1	25
H.L.R.	4	4	0	1	3
Total	53	103	12	9	81

* One of these pregnancies resulted in a mummified fetus.

During the four-year period, 1933-1936, the crossbred herd was represented by two females. Neither of these cows gave birth to a live calf. Cow E 109 was by the Jersey bull H.G.J. 3rd and out of the Guernsey cow E 36. This animal gave birth to two dead bull calves by Jersey bull F.O.O. Cow E 223 was by the Jersey bull R.R. and out of the Guernsey cow E 144. This animal gave birth to one dead bull calf by the Jersey bull N.P.G.

Table 6. Percentage of pregnancies that resulted in calves born dead, by breeds.

Years	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900-1939	4.7	8.0	0.0	6.3	5.1
1900-1932	4.1	8.5	0.0	3.2	4.4
1900-1927	2.9	6.2	0.0	1.8	3.1
1928-1932	11.3	12.5	0.0	16.6	10.5
1933-1936	8.8	3.7	0.0	100.0	8.0
1937-1938	7.7	6.6			7.3
1933-1938	8.4	4.8	0.0	100.0	7.8
1939	3.8	23.1*			10.3

Holsteins were in the herd, 1913-1939; Guernseys, 1919-1934; crossbreds, 1912-1935.

*There seems to be no adequate explanation for the high percent of calves born dead. It may be significant that all were sired by the same bull.

Table 6 shows the percentage of pregnancies of normal duration that resulted in the calves being born dead, for the entire period, as well as for the different Bang's disease and genital trichomoniasis periods. Table 17 in the appendix shows the number of calves born dead for the entire period by years and by breeds.

Calf mortality is usually not considered in a summary of the

⁴ Metzger, H. J., F. E. Hull, and Fordyce Ely. Albuminuria and nephritis in dairy cows. Ky. Agr. Exp. Sta. Bul. 373. 1937.

reproductive efficiency of dairy cattle altho it is a serious problem in the average dairy herd. Better breeding hygiene and the eradication of Bang's disease results in calves that are stronger at birth and less susceptible to disease. Of the 1169 calves born alive in the Kentucky Agricultural Experiment Station dairy herd during the forty years covered by this analysis 109, or 9.3 percent, lived less than six months.

For the twenty-eight years previous to beginning the eradication of Bang's disease the calf mortality was 12.1 percent. During the time that Bang's disease eradication was in progress, 1928-1932, considerable attention was given to breeding hygiene, calf-barn sanitation and the feeding and care of calves. The calf mortality dropped to 3.7 percent for this period.

Bang's disease was entirely eliminated from the herd January 1, 1933. During the next six years, 1933-1938, the death rate among calves born alive was 2.5 percent. For the first four years of this period, 1933-1936, the mortality of calves born alive was only 0.7 percent. During the last two years, 1937-1938, the mortality rate increased to 5.7 percent.

Table 7. Percentages of calves born alive that lived less than six months, by breeds.

Years	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900-1939	10.9	4.4	5.5	5.7	9.3
1900-1932	11.0	4.9	5.8	5.7	10.6
1900-1927	13.5	6.3	10.7	6.1	12.1
1928-1932	5.2	2.4	0.0	0.0	3.7
1933-1936	1.2	0.0	0.0	0.0	0.7
1937-1938	4.3	8.3			5.7
1933-1938	2.4	2.7	0.0	0.0	2.5
1939	12.0	11.1			11.8*

Holsteins were in the herd, 1913-1939; Guernseys, 1919-1934; crossbreds, 1912-1935.

*The high percent of mortality among calves was probably due to factors having no relation to their condition at birth.

Dairy calves are frequently rather weak at birth. This is especially true in herds that have a high incidence of genital disease. In such herds indigestion and calf scours usually cause considerable trouble. The presence of genital trichomoniasis in the Holstein herd during the 1937-1938 period may account for the increase in calf losses. The calves of all breeds were kept in the same barn and disease that originated in individuals of one breed could spread to individuals of another breed. Table 7 shows, by breed, the per-

percentage of calves born alive that lived but a short time. Table 8 in the appendix shows, for the entire period by years and by breeds, the number of calves born alive that lived less than six months.

A survey of dairy-herd records shows that replacement of breeding animals is a problem in the average dairy herd. Of the 1438 pregnancies that occurred in the Kentucky Agricultural Experiment Station dairy herd, from January 1, 1900, to December 31, 1939, 1060, or 73.7 percent, resulted in calves that grew to maturity. Of these animals, 565 were males and 495 were females. During this period 482 different females were in the breeding herd. Dairy herds are improved by breeding and selection of the better calves for breeders. As long as the reproductive efficiency is such that the majority of females that grow to maturity are required for replacement, selection is necessarily at a minimum.

In the final analysis the percentage of pregnancies that result in healthy calves that grow to maturity, as shown in table 8, is the true measure of the health and reproductive efficiency of a dairy herd. Table 19 in the appendix shows the number of calves that grew to maturity for the entire period, by years and by breeds.

Table 8. Percentage of pregnancies that resulted in calves that grew to maturity, by breeds.

Years	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900-1939	71.9	78.4	81.3	78.1	73.7
1900-1932	70.0	75.8	81.7	80.6	71.1
1900-1927	69.6	77.3	78.4	82.1	71.5
1928-1932	72.6	73.2	86.9	66.6	74.2
1933-1936	78.4	92.6	75.0	0.0	82.1
1937-1938	84.6	73.3			80.5
1933-1938	80.5	85.7	75.0	0.0	81.6
1939	84.6	61.5			76.9

Holsteins were in the herd, 1913-1939; Guernseys, 1919-1934; crossbreds, 1912-1935.

SUMMARY

Data on the reproductive efficiency of the females in the Kentucky Agricultural Experiment Station dairy herd prior to 1940 are summarized in six periods as follows. The entire period, 1900 to 1939, inclusive; 1900 to 1927, inclusive, during which time no organized program for the control of Bang's disease or other diseases except tuberculosis was in operation; 1928 to 1932, inclusive, during

which time intensive health supervision and a definite program for Bang's disease eradication were in operation, resulting in the elimination of Bang's disease from the herd; 1933 to 1936, inclusive during which time the herd was free from Bang's disease and trichomoniasis; 1937 and 1938, during which time trichomoniasis infection occurred in the herd; and 1939.

The average calving interval per cow for each period, was 16.7, 17.2, 18.0, 14.2, 15.7 and 12.7 months, respectively. These calving intervals when expressed as reproductive efficiency are 71.8, 69.8, 66.7, 84.5, 76.4 and 94.5 percent, respectively.

The percentage of known pregnancies that resulted in observed abortions, for each period, was 13.6, 15.6, 12.4, 9.3, 7.3 and 2.6 percent, respectively.

The percentage of pregnancies that resulted in calves born dead for each period was 5.1, 3.1, 10.5, 8.0, 7.3 and 10.3 percent, respectively.

The percentage of calves born alive that lived less than six months for each period was 9.3, 12.1, 3.7, 0.7, 5.7 and 11.8 percent, respectively.

The percentage of pregnancies which resulted in calves that grew to maturity, for each period was 73.7, 71.5, 74.2, 82.1, 80.5 and 76.9 percent, respectively.

CONCLUSIONS

1. Intensive health supervision, the control of diseases in general and the eradication of Bang's disease have aided materially in raising the reproductive efficiency and shortening the calving interval of the cows in the dairy herd of the Kentucky Agricultural Experiment Station.

2. The ideal of 100 percent reproductive efficiency, or a twelve month's calving interval, may be more nearly approached by the continued application of intensive health measures, a carefully planned mating program and added attention to nutritional and genetic influences.

REFERENCES

- Cannon, C. Y. and D. L. Espe. Changes occurring in freshening dates from year to year of cows in Iowa testing associations. *Jour. of Dairy Sci.* 20:401-402. 1937.
- Clark, C. F. Correlation of blood reactions with the breeding records over a period of years in an abortion-infected herd of cattle. *Jour. Am. Vet. Med. Assoc. N.S.* 32:290-331. 1931.
- Clark, C. F. Experiences in eradicating Bang's disease in three infected herds of cattle. *Jour. Am. Vet. Med. Assoc. N.S.* 34:54-61. 1932.
- Dawson, J. R. The breeding efficiency of proved (aged) sires. *Jour. of Dairy Sci.* 21:725-737. 1938.
- Dimock, W. W. Prevention and eradication of Bang's disease. *Ky. Agr. Expt. Sta. Cir.* 41. 1934.
- Eckles, C. H. A study of breeding records of dairy herds. *Minn. Agr. Expt. Sta. Bul.* 258. 1929.
- Ely, Fordyce, F. E. Hull and H. B. Morrison. Agnathia, a new bovine lethal. *Jour. of Heredity* 30:104-108. 1939.
- Fitch, C. P., W. L. Boyd and A. L. Delez. Report of experimental work in the control of bovine infectious abortion. *Jour. Am. Vet. Med. Assoc. N.S.* 28:215-229. 1929.
- Fohrman, M. H., R. R. Graves. Experiments in breeding Holstein-Friesian cattle for milk and butterfat-producing ability, and an analysis of the foundation cows and of the first outbred generation. *U. S. Depart. of Agric. Tech. Bul.* 677. 1939.
- Fritz, B. Scott and M. F. Barnes. Bang disease control work in fourteen state institution herds. *Jour. Am. Vet. Med. Assoc. N.S.* 29:490-504. 1930.
- Fritz, B. Scott and M. F. Barnes. Bang disease control work in fourteen state institution herds. II. Progress report to 1931. *Jour. Am. Vet. Med. Assoc. N.S.* 36:680-691. 1933.
- Fritz, B. Scott and M. F. Barnes. Bang disease control in state institution herds. III and IV. Progress reports on the 16 herds for 1931 and 1932. *Jour. Am. Vet. Assoc. N.S.* 40:542-558. 1935.
- Lothe, Herbert. The breeding efficiency of a herd of cows negative to the agglutination test for abortion. *Jour. Am. Vet. Med. Assoc. N.S.* 28:148-168. 1929.
- Mead, S. W. A diagrammatic method of presenting the history of reproduction in a dairy herd. *Jour. of Dairy Sci.* 21:283-287. 1938.
- Mead, S. W. and W. M. Regan. Analysis of dairy herd breeding records. *Jour. of Dairy Sci.* 22:468-469. 1939.
- Metzger, H. J., F. E. Hull and Fordyce Ely. Albuminuria and nephritis in dairy cows. *Ky. Agr. Exp. Sta. Bul.* 373. 1937.
- Morgan, R. F. and H. P. Davis. Influence of age of dairy cattle and season of the year on the sex ratio of calves and services required for conception. *Neb. Agr. Exp. Sta. Res. Bul.* 104. 1938.
- Spielman, Arless and I. R. Jones. The inheritance of fertility in dairy cattle. *Jour. of Dairy Sci.* 22:468. 1939.
- Williams, W. L. A standard for measuring the reproductive and dairying efficiency of cattle. *The Cornell Vet.* 9:204-213. 1919.
- Williams, W. W. Observations on reproduction in a purebred dairy herd. *The Cornell Vet.* 12:19-42.

APPENDIX

Table 9. Percentage distribution of females of breeding age in the herd, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred
	Percent	Percent	Percent	Percent
1900	100.0			
1901	100.0			
1902	100.0			
1903	100.0			
1904	100.0			
1905	100.0			
1906	100.0			
1907	100.0			
1908	100.0			
1909	100.0			
1910	100.0			
1911	100.0			
1912	94.7			5.3
1913	81.3	6.2		12.5
1914	83.7	5.4		10.9
1915	83.0	5.1		11.9
1916	76.3	10.2		13.5
1917	71.4	12.3		16.3
1918	69.8	16.3		13.9
1919	58.3	18.8	8.3	14.6
1920	62.0	18.0	8.0	12.0
1921	61.4	21.0	8.8	8.8
1922	63.0	16.7	11.1	9.2
1923	65.0	18.3	10.0	6.7
1924	66.2	21.5	7.7	4.6
1925	59.7	25.0	12.5	2.8
1926	52.3	27.7	15.4	4.6
1927	58.5	24.6	12.3	4.6
1928	54.1	27.0	14.8	4.1
1929	56.5	24.7	15.9	2.9
1930	61.7	22.1	14.7	1.5
1931	63.1	23.1	12.3	1.5
1932	56.7	29.9	11.9	1.5
1933	62.7	31.3	4.5	1.5
1934	65.0	28.4	3.3	3.3
1935	72.4	25.9		1.7
1936	69.0	31.0		
1937	60.3	39.7		
1938	60.6	39.4		
1939	66.7	33.3		

Table 10. Number of females of breeding age in the herd, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	22				22
1901	34				34
1902	35				35
1903	48				48
1904	38				38
1905	45				45
1906	51				51
1907	52				52
1908	56				56
1909	59				59
1910	57				57
1911	54				54
1912	36			2	38
1913	39	3		6	48
1914	46	3		6	55
1915	49	3		7	59
1916	45	6		8	59
1917	35	6		8	49
1918	30	7		6	43
1919	28	9	4	7	48
1920	31	9	4	6	50
1921	35	12	5	5	57
1922	34	9	6	5	54
1923	39	11	6	4	60
1924	43	14	5	3	65
1925	43	18	9	2	72
1926	34	18	10	3	65
1927	38	16	8	3	65
1928	40	20	11	3	74
1929	39	17	11	2	69
1930	42	15	10	1	68
1931	41	15	8	1	65
1932	38	20	8	1	67
1933	42	21	3	1	67
1934	39	17	2	2	60
1935	42	15		1	58
1936	40	18			58
1937	38	25			63
1938	40	26			66
1939	38	19			57
Average	46.9a	13.8b	6.9c	3.9d	55.2a

a. 40 year average. b. 27 year average. c. 16 year average. d. 24 year average.

Table 11. Number of breeding-cow years for the herd, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	19.5				19.5
1901	26.7				26.7
1902	30.3				30.3
1903	31.5				31.5
1904	32.4				32.4
1905	38.9				38.9
1906	47.1				47.1
1907	41.4				41.4
1908	44.7				44.7
1909	47.8				47.8
1910	46.2				46.2
1911	40.3				40.3
1912	31.1			1.0	32.1
1913	33.7	1.0		4.9	39.6
1914	35.3	3.0		6.0	44.3
1915	41.5	3.0		6.6	51.1
1916	37.7	5.1		6.8	49.6
1917	29.3	5.0		5.9	40.2
1918	23.7	6.5		4.6	34.8
1919	24.7	7.6	3.0	6.0	41.3
1920	26.5	8.3	4.0	4.4	43.2
1921	28.2	8.9	4.7	3.5	45.3
1922	31.5	8.8	4.3	3.8	48.4
1923	35.1	8.7	5.8	4.0	53.6
1924	36.1	10.2	5.0	2.9	54.2
1925	35.4	15.8	6.3	1.8	59.3
1926	32.3	14.3	6.7	2.0	55.3
1927	31.1	15.5	7.2	3.0	56.8
1928	31.8	15.8	8.3	2.4	58.3
1929	29.3	14.9	9.5	1.4	55.1
1930	33.7	12.0	8.2	.3	54.2
1931	33.3	12.4	6.3	1.0	53.0
1932	31.5	16.6	3.7	1.0	52.8
1933	32.3	16.2	2.4	1.0	51.9
1934	30.7	12.2	1.2	1.5	45.6
1935	30.3	13.5		.7	44.5
1936	31.2	14.2			45.4
1937	29.7	20.5			50.2
1938	29.1	20.2			49.3
1939	34.8	15.3			50.1
Total 1900-1939	1337.7	305.5	86.6	76.5	1806.3
Total 1900-1932	1119.6	193.4	83.0	73.3	1469.3
Total 1900-1927	960.0	121.7	47.0	67.2	1195.9
Total 1928-1932	159.6	71.7	36.0	6.1	273.4
Total 1933-1936	124.5	56.1	3.6	3.2	187.4
Total 1937-1938	58.8	40.7			99.5
Total 1939	34.8	15.3			50.1

Table 12. Number of breeding-cow months for the herd, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	234				234
1901	321				321
1902	364				364
1903	378				378
1904	389				389
1905	467				467
1906	565				565
1907	497				497
1908	536				536
1909	574				574
1910	554				554
1911	484				484
1912	373			12	385
1913	404	12		59	475
1914	424	36		72	532
1915	498	36		79	613
1916	452	61		82	595
1917	352	60		71	483
1918	284	78		56	418
1919	296	91	36	72	495
1920	318	99	48	53	518
1921	338	107	56	42	543
1922	378	106	51	46	581
1923	421	104	70	48	643
1924	433	123	60	35	651
1925	425	189	76	22	712
1926	388	171	80	24	663
1927	373	186	86	36	681
1928	382	189	100	29	700
1929	351	179	114	17	661
1930	405	144	98	3	650
1931	400	149	75	12	636
1932	378	199	45	12	634
1933	387	195	29	12	623
1934	368	147	14	18	547
1935	364	162		8	534
1936	374	171			545
1937	356	246			602
1938	349	242			591
1939	418	184			602
Total 1900-1939	16052	3666	1038	920	21676
Total 1900-1932	13436	2319	995	882	17632
Total 1900-1927	11520	1459	563	809	14351
Total 1928-1932	1916	860	432	73	3281
Total 1933-1936	1493	675	43	38	2249
Total 1937-1938	705	488			1193
Total 1939	418	184			602

Table 13. Calves born and equivalent in pregnancies, 1900 to 1939, 1 breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	10.0				10.0
1901	22.3				22.3
1902	13.3				13.3
1903	24.3				24.3
1904	22.7				22.7
1905	19.9				19.9
1906	36.1				36.1
1907	25.9				25.9
1908	27.9				27.9
1909	38.0				38.0
1910	29.1				29.1
1911	21.8				21.8
1912	14.0			0.0	14.0
1913	23.2	0.2		4.0	27.4
1914	18.6	2.7		5.0	26.3
1915	27.7	1.8		5.3	34.8
1916	32.4	3.6		4.9	40.9
1917	22.6	4.8		4.2	31.6
1918	19.9	5.8		4.0	29.7
1919	23.3	4.9	2.7	3.7	34.6
1920	16.6	4.3	3.5	4.0	28.4
1921	17.6	6.9	4.0	2.2	30.7
1922	21.7	5.1	3.7	3.5	34.0
1923	22.0	7.4	4.3	2.4	36.1
1924	23.0	8.4	3.5	3.0	37.9
1925	27.0	12.1	2.2	1.9	43.2
1926	29.4	10.9	4.0	1.8	46.1
1927	24.7	13.3	5.9	2.7	46.6
1928	19.4	10.7	6.0	1.8	37.9
1929	20.1	10.6	4.8	0.9	36.4
1930	24.1	10.4	3.2	0.0	37.7
1931	20.9	7.7	3.2	0.0	31.8
1932	24.0	11.5	1.8	1.0	38.3
1933	27.5	15.0	1.7	1.0	45.2
1934	25.2	12.1	0.6	1.3	39.2
1935	22.8	13.2		0.6	36.6
1936	23.6	13.7			37.3
1937	24.5	14.2			38.7
1938	25.3	11.8			37.1
1939	33.2	14.1			47.3
Total 1900-1939	945.6	237.2	55.1	59.2	1297.1
Total 1900-1932	763.5	143.1	52.8	56.3	1015.7
Total 1900-1927	655.0	92.2	33.8	52.6	833.6
Total 1928-1932	108.5	50.9	19.0	3.7	182.1
Total 1933-1936	99.1	54.0	2.3	2.9	158.3
Total 1937-1938	49.8	26.0			75.8
Total 1939	33.2	14.1			47.3

Table 14. Number of breeding-cow months per calf, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	23.4				23.4
1901	14.4				14.4
1902	27.4				27.4
1903	15.6				15.6
1904	17.1				17.1
1905	23.5				23.5
1906	15.7				15.7
1907	19.2				19.2
1908	19.2				19.2
1909	15.1				15.1
1910	19.0				19.0
1911	22.2				22.2
1912	26.6			—	27.5
1913	17.4	60.0		14.7	17.3
1914	22.8	13.3		14.4	20.2
1915	18.0	20.0		14.9	17.6
1916	13.9	16.9		16.7	14.5
1917	15.6	12.5		16.9	15.3
1918	14.3	13.4		14.0	14.1
1919	12.7	18.6	13.3	19.5	14.3
1920	19.2	23.0	13.7	13.2	18.2
1921	19.2	15.5	14.0	19.1	17.7
1922	17.4	20.8	13.8	13.1	17.1
1923	19.1	14.0	16.3	20.0	17.8
1924	18.8	14.6	17.1	11.7	17.2
1925	15.7	15.6	34.5	11.6	16.5
1926	13.2	15.7	20.0	17.2	14.4
1927	15.1	14.0	14.6	13.3	14.6
1928	19.7	17.7	16.7	16.1	18.5
1929	17.5	16.9	23.7	18.9	18.2
1930	16.8	13.8	30.6	—	17.2
1931	19.1	19.3	23.4	—	20.0
1932	15.7	17.3	25.0	12.0	16.5
1933	14.1	13.0	17.1	12.0	13.8
1934	14.6	12.1	23.3	13.8	13.9
1935	16.0	12.3		12.2	14.6
1936	15.8	12.5			14.6
1937	14.5	17.3			15.5
1938	13.8	20.5			15.9
1939	12.6	13.0			12.7
Weighted av. 1900-1939	17.0	15.5	18.8	15.5	16.7
Weighted av. 1900-1932	17.6	16.2	18.8	15.7	17.4
Weighted av. 1900-1927	17.6	15.8	16.6	15.4	17.2
Weighted av. 1928-1932	17.6	16.9	22.7	19.7	18.0
Weighted av. 1933-1936	15.1	12.5	18.7	13.1	14.2
Weighted av. 1937-1938	14.2	18.8			15.7
Average 1939	12.6	13.0			12.7

Table 15. Reproductive efficiency of females of breeding age in the herd, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
	Percent	Percent	Percent	Percent	Percent
1900	51.3				51.3
1901	83.3				83.3
1902	43.8				43.8
1903	76.9				76.9
1904	70.2				70.2
1905	51.1				51.1
1906	76.4				76.4
1907	62.5				62.5
1908	62.5				62.5
1909	79.5				79.5
1910	63.2				63.2
1911	54.0				54.0
1912	45.1			0.0	43.6
1913	69.0	20.0		81.6	69.4
1914	52.6	90.2		83.3	59.4
1915	66.7	60.0		80.5	68.2
1916	86.3	71.0		71.8	82.7
1917	76.9	96.0		71.0	78.4
1918	83.9	89.6		85.7	85.1
1919	94.5	64.5	90.2	61.5	83.9
1920	62.5	52.2	87.6	90.9	65.9
1921	62.5	77.4	85.7	62.8	67.8
1922	69.0	57.7	86.9	91.6	70.2
1923	62.8	85.7	73.6	60.0	67.4
1924	63.8	82.2	70.2	102.6	69.8
1925	76.4	76.9	34.8	103.4	72.7
1926	90.9	76.4	60.0	69.8	83.3
1927	79.5	85.7	82.2	90.2	82.2
1928	60.9	67.8	71.8	74.5	64.9
1929	68.6	71.0	50.6	63.5	65.9
1930	71.4	86.9	39.2	0.0	69.8
1931	62.8	62.2	51.3	0.0	60.0
1932	76.4	69.4	48.0	100.0	72.7
1933	85.1	92.3	70.2	100.0	86.9
1934	82.2	99.2	51.5	86.9	86.3
1935	75.0	97.6		98.4	82.2
1936	75.9	96.0			82.2
1937	82.7	69.4			77.4
1938	86.9	58.5			75.5
1939	95.2	92.3			94.5
Weighted av. 1900-1939	70.6	77.4	63.8	77.4	71.8
Weighted av. 1900-1932	68.2	74.1	63.8	76.4	69.0
Weighted av. 1900-1927	68.2	75.9	72.3	77.9	69.8
Weighted av. 1928-1932	68.2	71.0	52.9	60.9	66.7
Weighted av. 1933-1936	79.5	96.0	64.2	91.6	84.5
Weighted av. 1937-1938	84.5	63.8			76.4
Average 1939	95.2	92.3			94.5

Table 16. Number of abortions, 1900 to 1939, by breeds

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	1				1
1901	2				2
1902	4				4
1903	1				1
1904	6				6
1905	3				3
1906	2				2
1907	11				11
1908	6				6
1909	7				7
1910	10				10
1911	7				7
1912	10			0	10
1913	3	0		0	3
1914	7	0		1	8
1915	4	1		0	5
1916	2	0		1	3
1917	2	0		1	3
1918	0	1		0	1
1919	2	0	0	1	3
1920	4	4	0	0	8
1921	6	1	0	1	8
1922	8	2	0	0	10
1923	9	0	1	1	11
1924	1	2	2	0	5
1925	5	0	2	0	7
1926	1	0	0	0	1
1927	2	0	0	0	2
1928	3	0	0	0	3
1929	0	3	0	0	3
1930	5	1	2	0	8
1931	6	2	1	1	10
1932	1	1	0	0	2
1933	3	1	1	0	5
1934	1	0	0	0	1
1935	3	1		0	4
1936	5	0			5
1937	1	2			3
1938	1	2			3
1939	0	1			1
Total 1900-1939	155	25	9	7	196
Total 1900-1932	141	18	8	7	174
Total 1900-1927	126	11	5	6	148
Total 1928-1932	15	7	3	1	26
Total 1933-1936	12	2	1	0	15
Total 1937-1938	2	4			6
Total 1939	0	1			1

Table 17. Number of calves born dead, 1900 to 1939, by breeds.

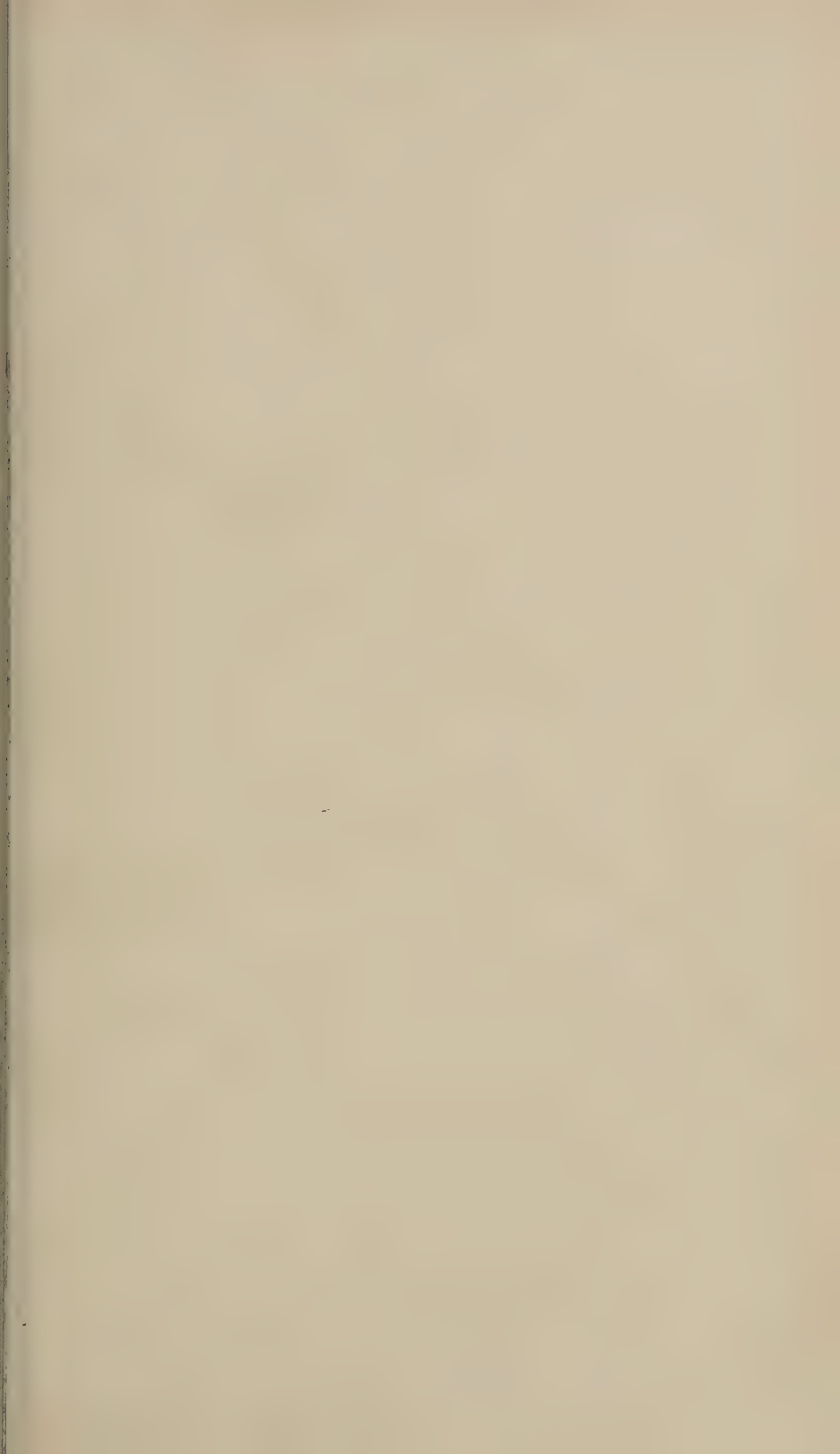
Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	0				0
1901	0				0
1902	1				1
1903	1				1
1904	0				0
1905	1				1
1906	0				0
1907	0				0
1908	0				0
1909	0				0
1910	1				1
1911	0				0
1912	0			0	0
1913	0	0		1	1
1914	0	0		0	0
1915	0	0		0	0
1916	0	0		0	0
1917	0	0		0	0
1918	2	0		0	2
1919	1	0	0	0	1
1920	0	0	0	0	0
1921	0	1	0	0	1
1922	1	1	0	0	2
1923	3	0	0	0	3
1924	4	1	0	0	5
1925	3	0	0	0	3
1926	1	1	0	0	2
1927	3	2	0	0	5
1928	3	2	0	0	5
1929	2	1	0	0	3
1930	3	0	0	0	3
1931	4	1	0	0	5
1932	2	3	0	1	6
1933	5	0	0	1	6
1934	3	0	0	0	3
1935	0	1		1	2
1936	1	1			2
1937	2	0			2
1938	2	2			4
1939	1	3			4
Total 1900-1939	50	20	0	4	74
Total 1900-1932	36	13	0	2	51
Total 1900-1927	22	6	0	1	29
Total 1928-1932	14	7	0	1	22
Total 1933-1936	9	2	0	2	13
Total 1937-1938	4	2			6
Total 1939	1	3			4

Table 18. Number of calves born alive that lived less than six months, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	0				0
1901	1				1
1902	4				4
1903	3				3
1904	1				1
1905	0				0
1906	4				4
1907	0				0
1908	1				1
1909	1				1
1910	7				7
1911	6				6
1912	1			0	1
1913	2	0		0	2
1914	3	0		0	3
1915	1	0		0	1
1916	3	0		0	3
1917	9	1		0	10
1918	5	1		1	7
1919	7	2	0	0	9
1920	3	0	0	0	3
1921	3	0	1	1	5
1922	2	0	1	0	3
1923	2	0	0	0	2
1924	3	0	0	0	3
1925	1	0	0	0	1
1926	6	0	1	0	7
1927	3	1	0	1	5
1928	5	0	0	0	5
1929	0	1	0	0	1
1930	0	0	0	0	0
1931	0	0	0	0	0
1932	0	0	0	0	0
1933	0	0	0	0	0
1934	0	0	0	0	0
1935	1	0		0	1
1936	0	0			0
1937	2	1			3
1938	0	1			1
1939	3	1			4
Total 1900-1939	93	9	3	3	108
Total 1900-1932	87	6	3	3	99
Total 1900-1927	82	5	3	3	93
Total 1928-1932	5	1	0	0	6
Total 1933-1936	1	0	0	0	1
Total 1937-1938	2	2			4
Total 1939	3	1			4

Table 19. Number of calves that grew to maturity, 1900 to 1939, by breeds.

Year	Jersey	Holstein	Guernsey	Crossbred	Whole Herd
1900	12				12
1901	15				15
1902	11				11
1903	17				17
1904	24				24
1905	14				14
1906	29				29
1907	25				25
1908	24				24
1909	36				36
1910	23				23
1911	17				17
1912	17			0	17
1913	17	0		1	18
1914	19	2		5	26
1915	26	2		5	33
1916	24	3		5	32
1917	22	2		5	29
1918	9	4		2	15
1919	14	6	2	5	27
1920	14	3	3	3	23
1921	15	4	3	2	24
1922	17	7	3	2	29
1923	16	7	3	3	29
1924	16	4	5	3	28
1925	17	11	3	2	33
1926	20	8	3	1	32
1927	16	12	4	2	34
1928	18	9	6	2	35
1929	15	7	6	2	30
1930	16	10	3	0	29
1931	22	8	3	0	33
1932	19	7	2	0	28
1933	23	16	1	0	40
1934	21	12	2	0	35
1935	23	11		0	34
1936	13	11			24
1937	24	9			33
1938	20	13			33
1939	22	8			30
Total 1900-1939	762	196	52	50	1060
Total 1900-1932	616	116	49	50	831
Total 1900-1927	526	75	29	46	676
Total 1928-1932	90	41	20	4	155
Total 1933-1936	80	50	3	0	133
Total 1937-1938	44	22			66
Total 1939	22	8			30



Kentucky Agricultural Experiment Station

University of Kentucky

THIRTY YEARS OF FARM PRICES AND PRODUCTION IN KENTUCKY

A COMPILATION OF AVAILABLE STATISTICS

BULLETIN NO. 403



Lexington, Ky.

May, 1940

CONTENTS

	Page
Introduction	191
Monthly prices and relatives of prices, Kentucky	
Major crops	195
Minor crops	226
Major livestock and livestock products	229
Minor livestock and livestock products	252
Acreage, production, price and farm value of crops in	
Kentucky	254
Fruits and vegetables	255
Grains	261
Hay	266
Seeds	270
Tobacco	273
Number and value of livestock on farms in Kentucky	276
Miscellaneous data.	283
Index	284

THIRTY YEARS OF FARM PRICES AND PRODUCTION IN KENTUCKY

A Compilation of Available Statistics

By A. J. BROWN and DANA G. CARD

Problems of an economic nature are constantly arising in agriculture that require for their analysis the use of price, production, and income data. It is the purpose of this bulletin to provide series of agricultural economic data for Kentucky that may be of use to farmers, county agents, agricultural students and teachers.

Most of the data are available in other publications but not in continuous series. The compilation of figures covering a series of years necessitates the use of several publications, some of which are to be found only in a fairly well equipped agricultural library. Frequent revisions of the original data also complicate the collection of such series. In the preparation of the tables which follow, the latest available figures have been used, but later revisions, of course, may result in minor changes. Publications of the United States Department of Agriculture have been drawn upon for most of the price and production data. Prices of strawberries were obtained from strawberry marketing associations and monthly prices of tobacco sold in Kentucky were compiled from reports made to the Kentucky State Department of Agriculture, Labor and Statistics, and are published here for the first time.

MONTHLY PRICES

Farm Products Other Than Tobacco and Strawberries. Prices received by producers for farm products sold about the 15th of each month are collected and compiled by the Division of Crop and Livestock Estimates of the United States Department of Agriculture. They are published currently in "Crops and Markets," a monthly publication of the Department, which may be used to continue many of the tables given on the following pages. Statistical Bulletin No. 6, "Prices of Farm Products Received by Producers, South Atlantic and South Central States," United States Department of Agriculture, contains prices on many Kentucky products from 1910 to 1925.

Information on prices received by producers is obtained each

month by means of questionnaires mailed to country merchants, elevator operators, well-informed farmers and various organizations to whom farmers sell their products. For the major crops the prices are averaged by crop-reporting districts (six in Kentucky), the average price in each district being weighted in accordance with production in that district in order to obtain the weighted average price for the State. For minor crops, livestock and livestock products, a simple arithmetic average of the prices by districts is used.¹

Monthly prices are not available for publication by crop-reporting districts in Kentucky, hence the prices used in this bulletin are average prices for the State. In a state of such diversified agriculture, with both surplus and deficit areas for certain commodities, the price in any one area may differ considerably from the average for the state as a whole. The state average price of a farm commodity, therefore, is not strictly applicable for use by the individual farmer, yet it should prove of value to him in his production and marketing plans by indicating the trend of price movements.

Certain consideration should be kept in mind when using these prices: (1) the prices are the average of all grades being marketed, and the average grade may vary from month to month; (2) the price represents the value of the product when it first leaves the farmers' hands; (3) the price is an average for the state as a whole rather than for any local community.

In the analysis of prices received by producers in Kentucky, due consideration should always be given to the dependence of Kentucky prices on national and world supplies. Tobacco is the only major commodity produced in Kentucky of which over 10 percent of the nation's supply is produced in this State.

Tobacco Prices. Monthly prices of tobacco are not reported on the 15th of each month as is the case for many farm products. The multiplicity of types of tobacco produced in the United States and the relatively concentrated areas of their production, make it impracticable to gather price information by means of the general price questionnaires. Monthly prices of the six types of tobacco grown in Kentucky have been compiled mainly from reports made to the Kentucky Commissioner of Agriculture.

Reports showing the amount of tobacco sold for growers and dealers are required each month from warehouses where auction

¹ For further information see "The Crop and Livestock Reporting Service of the United States." Miscellaneous Publication 171, U. S. D. A.

ales are held. Prices given in the tables which follow are those paid for tobacco sold by growers on the auction floors. When sales are made at the barn to dealers or company buyers, they are not represented in the price quotations. The omission of barn sales is most important for the fire-cured types grown in Western Kentucky.

Two series of annual prices for tobacco will be found on the following pages. Weighted average prices for the crop year, based on sales in Kentucky warehouses, are given in Tables 19 to 30. These do not include barn-door sales. Tables 99 to 104 give season's average prices which do allow for barn-door sales. These are computed by the United States Department of Agriculture. Slight differences will be noted in the two series for Burley, One Sucker, and Green River tobaccos, in which barn-door sales are relatively unimportant, and marked differences for the fire-cured tobaccos of Western Kentucky. Monthly prices which include sales at the barn are not available.

The prices given are for tobacco sold in Kentucky and should not be used as prices for all tobacco of the respective types grown in the United States.

PRICE RELATIVES AND GRAPHIC PRESENTATION

"Price relative" is the term ordinarily used to express the price of an individual commodity at one time in percent of the price of the same commodity at some other time. For this bulletin price relatives were calculated for all commodities, other than tobacco, by setting the average of the annual prices for the years 1921-1929 equal 100 and expressing each monthly price in percent of that average. In the case of tobacco the average of the crop year prices 1920-1929 was used to equal 100.

With the exception of those for apples and potatoes, the charts showing monthly prices for the various commodities are drawn on a comparable scale. Two scales are used on each chart, the actual price and the corresponding price relative. The price relative scale (right) is drawn to the same dimensions for all of the charts (except apples and potatoes) so they are directly comparable. The extreme fluctuation in the prices of apples and potatoes during the period covered by the charts necessitated the reduction of the price relative scale by one-third for these two commodities. A product which varies widely in price such as eggs (figure 20) shows wide fluctuations on the chart while one which varies less, such as chickens (figure 19), shows smaller fluctuations.

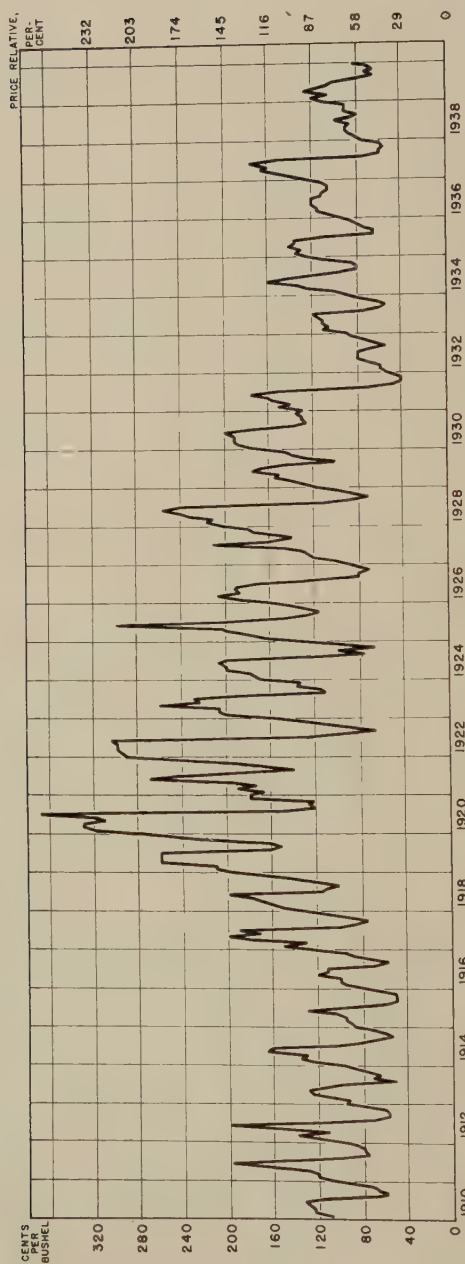


Figure 1. Apples. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices showed wide seasonal movements and were lowest in September, October and November, the months of heaviest marketings, and highest in the months when producers have few apples for sale. This chart along with that for potatoes is drawn on a price-relative scale of one-third less than the other charts of monthly prices.

MAJOR CROPS

Table 1. Apples. Prices received by Kentucky producers on the 15th of the month, 1910- (cents per bushel).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
111	123	126	128	133	116	67	60	67	72	90	110	83
120	120	130	155	198	150	98	74	79	80	85	99	91
120	140	110	150	200	121	70	56	56	60	75	95	75
93	110	125	130	115	100	50	70	65	75	88	95	80
125	135	130	165	160	105	82	68	52	60	70	87	74
90	95	95	105	130	98	60	48	50	51	62	80	62
95	100	100	120	110	110	69	56	69	88	95	125	89
150	130	180	200	170	190	100	85	75	90	110	130	104
150	160	170	180	200	115	110	100	120	140	165	195	143
210	200	260	260	260	260	160	150	160	220	250	280	216
320	330	330	310	320	370	150	120	125	121	180	180	165
165	190	175	195	270	245	185	140	165	195	250	290	201
295	300	300	300	305	130	95	65	90	108	130	155	134
200	205	206	259	225	229	185	110	114	137	134	169	149
175	180	200	200	205	200	125	77	99	65	106	135	101
167	180	197	203	300	200	149	128	116	128	142	163	141
190	205	186	190	189	165	110	80	80	70	80	90	94
100	120	125	130	150	210	160	140	150	175	180	200	166
215	210	230	240	255	240	110	85	70	85	100	120	110
130	140	155	150	175	165	145	100	125	140	145	175	142
185	190	190	190	200	175	140	125	130	130	135	130	140
150	140	155	160	175	150	70	50	40	40	45	55	60
60	60	70	80	80	80	70	55	65	75	85	90	74
110	105	110	110	115	120	75	60	55	65	80	90	74
100	125	135	160	145	120	95	80	80	85	110	125	96
135	130	140	135	135	110	65	65	75	80	85	95	88
105	115	115	120	120	120	110	110	105	105	110	125	109
140	155	165	160	175	150	75	60	60	55	60	75	75
80	85	90	90	85	100	85	80	90	90	90	110	91
120	105	125	115	105	100	80	65	70	65	70	85	76

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.
² calendar year, weighted by average monthly marketings, 1926-1930.

Table 2. Apples. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
80	89	91	93	96	84	49	43	49	52	65	80	60
87	87	94	112	143	109	71	54	57	58	62	72	66
87	101	80	109	145	88	51	41	41	43	54	69	54
67	80	91	94	83	72	36	51	47	54	64	69	58
91	98	94	120	116	76	59	49	38	43	51	63	54
65	69	69	76	94	71	43	35	36	37	45	58	45
69	72	72	87	80	80	50	41	50	64	69	91	64
109	94	130	145	123	138	72	62	54	65	80	94	75
109	116	123	130	145	83	80	72	87	101	120	141	104
152	152	188	188	188	188	116	109	116	159	181	203	157
232	239	239	225	232	268	109	87	91	88	130	130	120
120	138	127	141	196	178	134	101	120	141	181	210	146
214	217	217	217	221	94	69	47	65	78	94	112	97
145	149	149	188	163	166	134	80	83	99	97	122	108
127	130	145	145	149	145	91	56	72	47	77	98	73
121	130	143	147	217	145	108	93	84	93	103	118	102
138	149	135	138	137	120	80	58	58	51	58	65	68
72	87	91	94	109	152	116	101	109	127	130	145	120
156	152	167	174	185	174	80	62	51	62	72	87	80
94	101	112	109	127	120	105	72	91	101	105	127	103
134	138	138	138	145	127	101	91	94	94	98	94	101
109	101	112	116	127	109	51	36	29	29	33	40	43
43	43	51	58	58	58	51	40	47	54	62	65	54
80	76	80	80	83	87	54	43	40	47	58	65	54
72	91	98	116	105	87	69	58	58	62	80	91	70
98	94	101	98	98	80	47	47	54	58	62	69	64
76	83	83	87	87	87	80	80	76	76	80	91	79
101	112	120	116	127	109	54	43	43	40	43	54	54
58	62	65	65	62	72	62	58	65	65	65	80	66
87	76	91	83	76	72	58	47	51	47	51	62	55

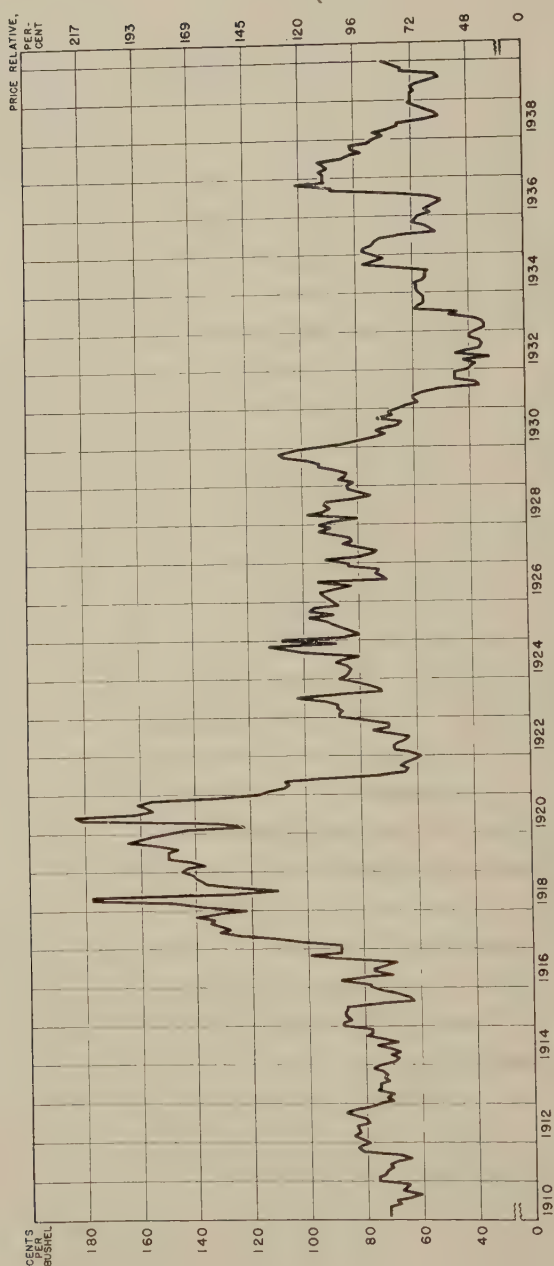


Figure 2. Barley. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices fell sharply in 1920 and 1921 but the general movement was similar to that of prices of the other grains. Barley is not a particularly important crop in Kentucky so monthly price quotations may be less reliable than those for more important farm products.

Table 3. Barley. Prices received by Kentucky producers on the 15th of the month, 1910- (cents per bushel).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
72	72	72	72	68	70	64	61	68	66	65	76	64
76	74	73	71	72	70	64	68	81	84	82	79	71
82	85	82	83	84	79	80	84	88	84	78	75	83
70	72	70	76	75	75	71	74	72	74	78	75	73
70	68	71	67	71	76	68	74	80	77	77	88	74
88	85	86	87	86	86	74	62	64	68	74	78	68
78	89	82	70	76	76	71	68	90	100	88	88	76
88	102	112	125	132	128	132	135	134	140	132	122	133
138	148	178	178	126	110	126	137	138	140	141	145	136
144	136	142	150	150	150	146	154	165	160	156	149	154
143	122	132	182	184	162	155	158	162	156	132	116	157
114	108	106	108	95	72	64	63	66	64	61	58	67
62	68	68	67	64	62	71	76	70	70	78	88	73
88	86	88	88	93	104	90	92	73	77	82	88	79
85	84	83	85	89	86	80	100	105	113	88	108	96
85	80	83	87	90	92	98	89	98	96	87	90	92
91	93	94	88	82	95	70	71	74	72	84	84	74
92	80	75	73	80	86	82	83	89	95	90	95	85
90	80	99	92	90	92	91	81	75	80	84	84	83
81	87	85	84	88	94	94	98	107	108	102	95	98
85	80	74	70	74	70	65	64	73	67	69	65	67
62	58	60	60	57	51	36	37	45	45	45	40	41
39	37	42	32	45	41	36	35	36	40	40	37	36
34	34	35	38	47	43	59	58	56	56	56	57	56
58	58	59	56	55	55	54	66	78	75	70	75	65
78	77	74	73	71	65	51	53	55	60	58	57	56
53	56	53	51	49	53	67	89	89	102	91	91	82
91	93	90	91	94	85	82	77	81	82	75	73	80
70	74	68	65	65	56	50	51	55	57	61	60	54
60	60	58	60	58	54	50	51	63	63	66	70	55

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.
For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 4. Barley. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1930 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
87	87	87	87	82	84	77	73	82	80	78	92	77
92	89	88	86	87	84	77	82	98	101	99	95	86
99	102	99	100	101	95	96	101	106	101	94	90	100
84	87	84	92	90	90	86	89	87	89	94	90	88
84	82	86	81	86	92	82	89	96	93	93	106	89
106	102	104	105	104	104	89	75	77	82	89	94	82
94	107	99	84	92	92	86	82	108	120	106	106	92
106	123	135	151	159	154	159	163	161	169	159	147	160
166	178	214	214	152	133	152	165	166	169	170	175	164
173	164	171	181	181	181	176	186	199	193	188	180	186
172	147	159	219	222	195	187	190	195	188	159	140	189
137	130	128	130	114	87	77	76	80	77	73	70	81
75	82	82	81	77	75	86	92	84	84	94	106	88
106	104	106	106	112	125	108	87	88	93	99	106	95
102	101	100	102	107	104	96	120	127	136	106	130	116
102	96	100	105	108	111	118	107	118	116	105	108	111
110	112	113	106	99	114	84	86	89	87	101	101	89
111	96	90	88	96	104	99	100	107	114	108	114	102
108	96	119	111	108	111	110	98	90	96	101	101	100
98	105	102	101	106	113	113	118	129	130	123	114	118
102	96	89	84	89	84	78	77	88	81	83	78	81
75	70	72	72	69	61	43	45	54	54	54	48	49
44	45	51	39	54	49	43	42	43	48	48	45	43
41	41	42	46	57	52	71	70	67	67	67	69	67
70	70	71	67	66	66	65	80	94	90	84	90	78
94	93	89	88	86	78	61	64	66	72	70	69	67
64	67	64	61	59	64	81	107	107	123	110	110	99
110	112	108	110	113	102	99	93	98	99	90	88	96
84	89	82	78	78	67	60	61	66	69	73	72	65
72	72	70	72	70	65	60	61	76	76	80	84	66

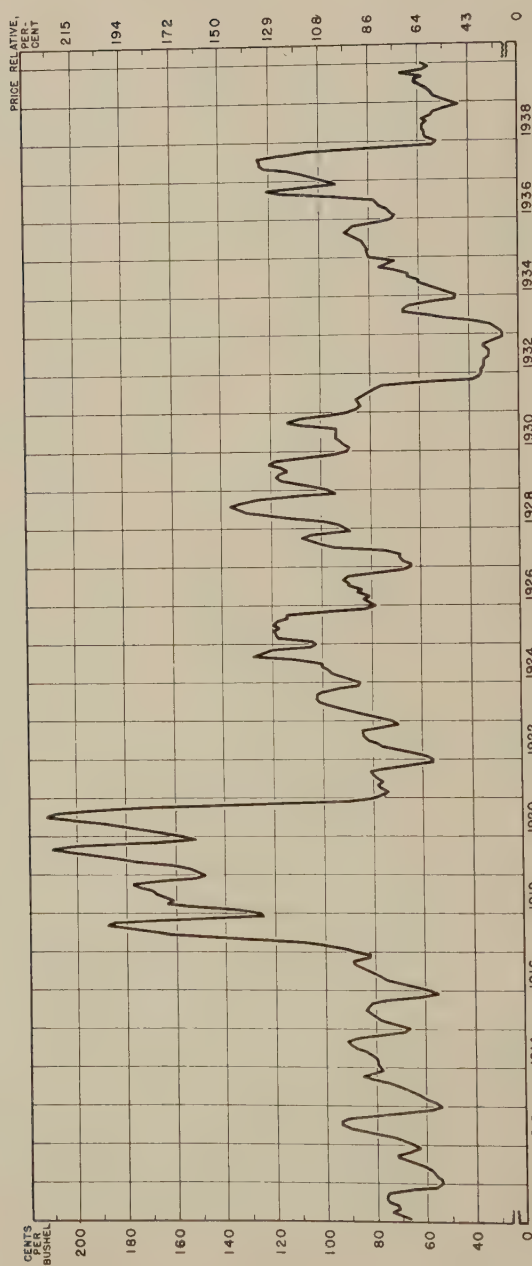


Figure 3. Corn. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

In the majority of years prior to 1929 a seasonal price movement is observable with highest prices in the months just preceding the harvest of a new crop. Corn prices from 1917 to 1920 were $2\frac{1}{2}$ times the prewar level and nearly double the level that prevailed during 1921-1929.

Table 5. Corn. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per bushel).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
67	71	74	72	72	75	76	76	75	66	56	54	68	
54	56	57	58	60	64	68	72	72	66	62	65	63	
68	72	78	85	91	94	94	91	83	68	57	54	76	
56	60	62	65	68	71	74	81	86	82	77	78	72	
79	79	80	82	84	88	90	91	88	79	68	66	79	
70	76	78	80	82	84	83	81	75	62	55	58	72	
64	70	75	77	80	83	86	88	88	82	82	88	81	
92	100	110	136	164	163	178	188	184	156	125	126	141	
135	154	164	162	166	168	169	175	178	167	152	148	160	
152	154	162	176	184	194	204	210	199	168	152	158	174	
166	175	182	190	202	212	208	193	170	128	90	80	158	
76	74	77	78	76	78	80	81	76	65	56	56	71	
59	64	71	76	79	82	84	84	84	76	70	72	74	
78	84	88	94	99	101	102	102	100	93	86	85	92	
89	94	97	98	100	100	110	127	125	120	104	102	104	
104	118	118	119	117	119	118	114	114	97	83	78	105	
81	84	81	86	84	89	89	91	89	80	67	64	80	
64	68	69	69	74	95	100	104	108	104	88	90	86	
93	98	111	120	130	133	137	132	126	111	94	98	113	
102	111	116	118	116	113	116	121	119	109	93	89	108	
88	91	92	94	94	94	94	107	113	109	96	89	96	
86	84	85	86	84	81	79	75	63	39	36	35	66	
35	34	34	34	33	33	33	34	34	31	27	27	32	
28	30	32	38	50	57	67	66	64	56	46	46	48	
48	52	57	60	60	65	65	71	76	73	70	80	66	
80	81	81	82	83	85	87	90	87	86	75	71	81	
70	72	73	76	77	78	94	114	121	105	93	97	89	
102	106	112	122	124	124	125	114	105	76	54	53	97	
57	58	58	59	59	57	59	55	54	50	44	47	54	
51	54	55	57	59	61	61	59	67	58	56	59	58	

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

²For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 6. Corn. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
72	76	80	77	77	81	82	82	81	71	60	58	73	
58	60	61	62	65	69	73	77	77	71	67	70	68	
73	77	84	91	98	101	101	98	89	73	61	58	82	
60	65	67	70	73	76	80	87	92	88	83	84	77	
85	85	86	88	90	95	97	98	95	85	73	71	85	
75	82	84	86	88	90	89	87	81	67	59	62	77	
69	75	81	83	86	89	92	95	95	88	88	95	87	
99	108	118	146	176	181	191	202	198	168	134	135	152	
145	166	176	174	178	181	182	188	191	180	163	159	172	
163	166	174	189	198	209	219	226	214	181	163	170	187	
178	188	196	204	217	228	224	208	183	138	97	86	170	
82	80	83	84	82	84	86	87	82	70	60	60	76	
63	69	76	82	85	88	90	90	90	82	75	77	80	
84	90	95	101	106	109	110	110	108	100	92	91	99	
96	101	104	105	108	108	118	137	134	129	112	110	112	
112	127	127	128	126	128	127	123	123	104	89	84	113	
87	90	87	92	90	96	96	98	96	86	72	69	86	
69	73	74	74	80	102	108	112	116	112	95	97	92	
100	105	119	129	140	143	147	142	135	119	101	105	122	
110	119	125	127	125	122	125	130	128	117	100	96	116	
95	98	99	101	101	101	101	115	122	117	103	96	103	
92	90	91	92	90	87	85	81	68	42	39	38	71	
38	37	37	37	35	35	35	37	37	33	29	29	34	
30	32	34	41	54	61	72	71	69	60	49	49	52	
52	56	61	65	65	70	70	76	82	78	75	86	71	
86	87	87	88	89	91	94	97	94	92	81	76	87	
75	77	78	82	83	84	101	123	130	113	100	104	96	
110	114	120	131	133	133	134	123	113	82	58	57	104	
61	62	62	63	63	61	63	59	58	54	47	51	58	
55	58	59	61	63	66	66	63	72	62	60	63	62	

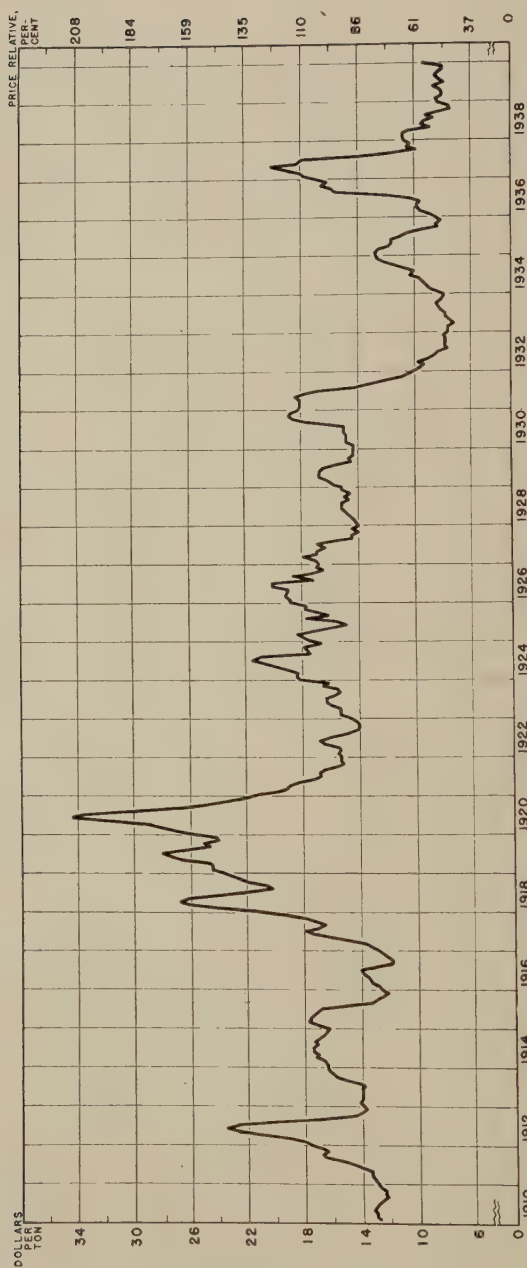


Figure 4. All hay (loose). Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Altho the general movement of hay prices was similar to that of the prices of important feed grains, certain differences occurred. Prices of hay during the war did not go to the heights of those of the feed grains and during 1922-1930 hay prices fluctuated less than those of the feed grains. Hay prices, except in the drouth period of 1936, have not recovered since 1932 even as much as grains, compared with prices that prevailed in the twenties.

Table 7. All hay (loose). Prices received by Kentucky producers on the 15th of the month, 1939¹ (dollars per ton).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
12.75	13.05	13.10	13.15	13.05	12.95	12.50	12.25	12.35	12.45	12.80	12.95	12.73
13.00	13.20	13.30	13.30	14.00	14.55	15.25	16.60	16.85	16.45	16.75	17.55	15.58
18.00	19.10	21.00	22.65	23.70	22.65	20.10	16.30	14.50	14.00	13.65	13.85	16.84
14.20	14.10	13.95	14.05	14.00	13.90	14.10	15.15	15.85	16.00	16.35	16.45	15.22
16.45	16.70	17.05	17.15	17.45	17.40	17.15	17.35	16.95	16.65	16.40	16.25	16.77
17.05	17.70	17.60	17.30	17.15	16.75	15.10	13.15	12.85	12.40	12.05	12.50	14.36
12.75	13.15	13.40	13.55	13.90	14.00	13.05	11.90	11.70	12.05	12.40	12.80	12.64
13.25	13.75	14.65	16.05	17.50	17.90	16.90	16.50	17.10	17.90	19.35	21.35	17.23
24.05	26.08	26.82	26.05	23.90	21.85	20.20	20.60	21.85	22.35	23.15	23.65	23.22
24.40	24.50	24.70	26.40	27.45	23.10	26.40	24.65	25.10	24.05	24.15	25.90	25.09
27.15	28.10	29.10	31.95	34.45	33.60	30.00	26.55	24.95	23.50	22.25	21.20	25.90
19.85	19.05	18.95	18.20	17.10	16.60	16.75	16.45	15.55	15.20	15.25	15.35	16.75
15.50	15.40	15.55	16.42	16.72	16.10	15.05	14.20	14.10	14.10	14.15	14.75	14.85
15.30	15.40	15.40	16.00	16.25	16.30	15.75	15.25	15.55	16.65	16.35	18.30	16.20
18.50	18.20	19.00	20.00	21.00	21.50	21.00	17.50	17.60	18.00	16.70	17.40	18.22
18.00	18.50	17.20	16.00	14.90	15.50	17.70	16.20	17.00	17.70	17.80	18.90	17.53
18.90	19.30	19.10	18.90	20.00	20.10	17.20	18.60	17.30	16.40	17.00	16.80	17.90
16.90	18.00	17.00	17.00	16.50	17.00	16.00	14.50	14.50	14.00	14.50	14.10	15.40
14.20	14.30	14.60	14.80	15.20	15.20	15.10	14.70	15.00	14.50	15.10	15.20	14.80
15.90	16.20	16.80	16.80	16.80	16.50	15.50	14.50	14.70	14.30	14.30	14.30	15.14
14.30	14.80	14.80	14.80	15.00	15.00	15.00	17.50	18.60	18.90	18.80	18.30	16.90
18.10	18.10	18.10	18.50	17.70	16.80	14.00	13.10	12.10	11.00	10.50	10.00	13.72
9.70	9.30	9.80	9.00	8.40	8.30	7.70	7.80	7.80	7.90	8.00	7.70	8.33
7.70	7.60	7.20	7.50	7.80	7.80	8.20	8.30	8.50	8.20	8.00	8.00	7.96
8.40	8.90	9.20	9.40	9.70	10.20	10.00	10.60	11.20	12.00	12.50	12.70	10.79
12.80	12.60	11.70	11.50	11.50	11.00	10.50	9.60	8.30	8.40	8.20	8.50	9.95
8.80	9.60	9.80	9.80	9.60	10.20	12.30	15.40	15.90	16.70	16.10	16.90	13.68
17.80	18.10	19.00	20.00	18.30	17.90	14.00	11.50	9.80	10.40	10.30	10.60	13.49
10.80	10.70	10.50	8.80	9.50	9.30	8.60	9.20	8.20	7.40	7.50	8.30	8.90
8.50	8.00	8.00	8.20	8.60	7.90	8.20	8.50	8.30	8.00	8.00	9.40	8.40

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.
For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 8. All hay (loose). Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
78	80	80	81	80	79	77	75	76	76	76	79	78
80	81	82	82	86	89	94	102	103	101	103	108	96
110	117	129	139	145	139	123	103	89	86	84	85	103
87	86	86	86	86	85	86	93	97	98	100	101	93
101	102	105	105	107	107	105	106	104	102	101	100	103
105	109	108	106	105	103	93	81	79	76	74	77	88
78	81	82	83	85	86	80	73	72	74	76	78	77
81	84	90	98	107	110	104	101	105	110	119	131	106
147	160	164	160	147	134	124	126	134	137	142	145	142
150	150	151	162	168	172	162	151	154	147	148	159	154
166	172	178	196	211	206	184	163	153	144	136	130	159
122	117	116	112	105	102	103	101	95	93	94	94	103
95	94	95	101	103	99	92	87	86	86	87	90	91
94	94	94	98	100	100	97	94	95	102	100	112	99
113	112	116	123	129	132	129	107	108	110	102	107	112
110	113	105	98	91	95	109	99	104	109	109	116	107
116	118	117	116	123	123	105	114	106	101	104	103	110
104	110	104	104	101	104	98	89	89	86	89	86	94
87	88	90	91	93	93	93	90	92	89	93	93	91
97	99	103	103	103	101	95	89	90	88	88	88	93
88	91	91	91	92	92	92	107	114	116	115	112	104
111	111	111	113	109	103	86	80	74	67	64	61	84
59	57	60	55	52	51	47	48	48	48	49	47	51
47	47	44	46	48	48	50	51	52	50	49	49	49
52	55	56	58	59	63	61	65	69	74	77	78	66
78	77	72	71	71	67	64	59	51	52	50	52	61
54	59	60	60	59	63	75	94	97	102	99	104	84
109	111	116	123	112	110	86	71	60	64	63	65	83
66	66	64	54	58	57	53	56	50	45	46	51	55
52	49	49	50	53	48	50	52	51	49	49	58	52

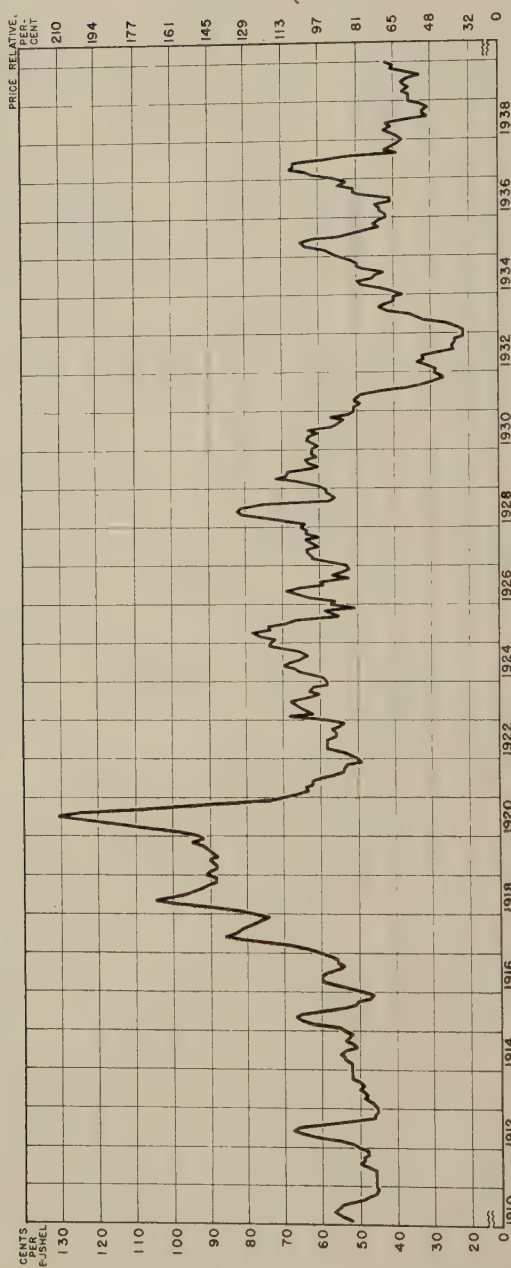


Figure 5. Oats. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Oat prices were more closely in line with hay prices than with corn prices, particularly in the war period and the twenties. The nationwide drouths in 1934 and 1936 were important factors in the price rises of 1935 and 1937.

Table 9. Oats. Prices received by Kentucky producers on the 15th of the month, 1910-1929 (cents per bushel).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
52	54	56	57	56	55	52	49	48	46	45	46	51	
46	46	46	46	46	48	50	49	49	48	48	50	48	
52	56	62	66	68	66	59	52	46	46	45	45	55	
46	47	49	48	49	50	49	50	52	52	52	52	50	
52	52	54	54	55	54	51	52	54	53	52	54	53	
56	62	66	67	66	60	54	51	50	47	46	49	55	
52	56	60	60	60	58	55	54	56	56	58	60	56	
63	68	74	82	86	83	82	80	78	76	74	78	78	
82	90	100	105	100	96	94	92	90	88	88	91	93	
90	88	88	89	90	88	89	90	92	95	92	93	90	
98	104	112	119	125	131	124	108	97	84	74	70	106	
66	63	64	62	62	60	56	54	54	53	49	50	57	
52	54	58	58	58	58	56	56	57	55	54	58	56	
69	62	64	66	67	68	63	60	63	62	58	58	63	
59	62	66	67	70	68	65	63	65	69	74	73	66	
72	76	79	73	74	69	67	55	56	59	51	57	64	
56	63	66	69	66	59	60	52	57	54	52	53	58	
57	62	62	63	63	60	62	64	60	64	63	65	62	
64	70	76	81	82	81	75	57	56	57	58	58	66	
61	66	72	69	69	63	60	63	64	61	62	62	64	
61	62	64	63	61	63	57	55	54	57	52	51	58	
51	49	51	50	49	44	37	33	30	27	28	30	38	
29	31	34	32	33	28	24	25	24	24	22	22	27	
22	24	26	32	34	36	42	44	43	40	40	38	37	
40	44	49	50	46	45	43	48	50	50	52	56	47	
57	58	64	65	62	55	51	48	44	46	44	42	52	
42	44	44	45	41	41	49	51	51	55	53	56	48	
62	64	68	67	67	59	53	39	42	41	39	38	51	
39	41	43	41	42	37	31	32	32	31	33	36	35	
36	36	38	36	37	38	36	33	38	41	40	42	36	

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

²For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 10. Oats. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

r	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
	84	87	90	92	90	89	84	79	77	74	73	74	82
	74	74	74	74	74	77	81	79	79	77	77	81	77
	84	90	100	106	110	106	95	84	74	74	73	73	89
	74	76	79	77	79	81	79	81	84	84	84	84	81
	84	84	87	87	89	87	82	84	87	85	84	87	85
	90	100	106	108	106	97	87	82	81	76	74	79	89
	84	90	97	97	97	94	89	87	90	90	94	97	90
	102	110	119	132	139	134	132	129	126	123	119	126	126
	132	145	161	169	161	155	152	148	145	142	142	147	150
	145	142	142	144	145	142	144	145	148	153	148	150	145
	158	168	181	192	202	211	200	174	156	135	119	113	171
	106	102	103	100	100	97	90	87	87	85	79	81	92
	84	87	94	94	94	94	90	90	92	89	87	94	90
	111	100	103	106	108	110	102	97	102	100	94	94	102
	95	100	106	108	113	110	105	102	105	111	119	118	106
	116	123	127	118	119	111	108	89	90	95	82	92	103
	90	102	106	111	106	95	97	84	92	87	84	85	94
	92	100	100	102	102	97	100	103	97	103	102	105	100
	103	113	123	131	132	131	121	92	90	92	94	94	106
	98	106	116	111	111	102	97	102	103	98	100	100	103
	98	100	103	102	98	102	92	89	87	92	84	82	94
	82	79	82	81	79	71	60	53	48	44	45	48	61
	47	50	55	52	53	45	39	40	39	39	35	35	44
	35	39	42	52	55	58	68	71	69	65	65	61	60
	65	71	79	81	74	73	69	77	81	81	84	90	76
	92	94	103	105	100	89	82	77	71	74	71	68	84
	68	71	71	73	66	66	79	82	82	89	85	90	77
	100	103	110	108	108	95	85	63	68	66	63	61	82
	63	66	69	66	68	60	50	52	52	50	53	58	56
	58	58	61	58	60	61	58	53	61	66	65	68	58

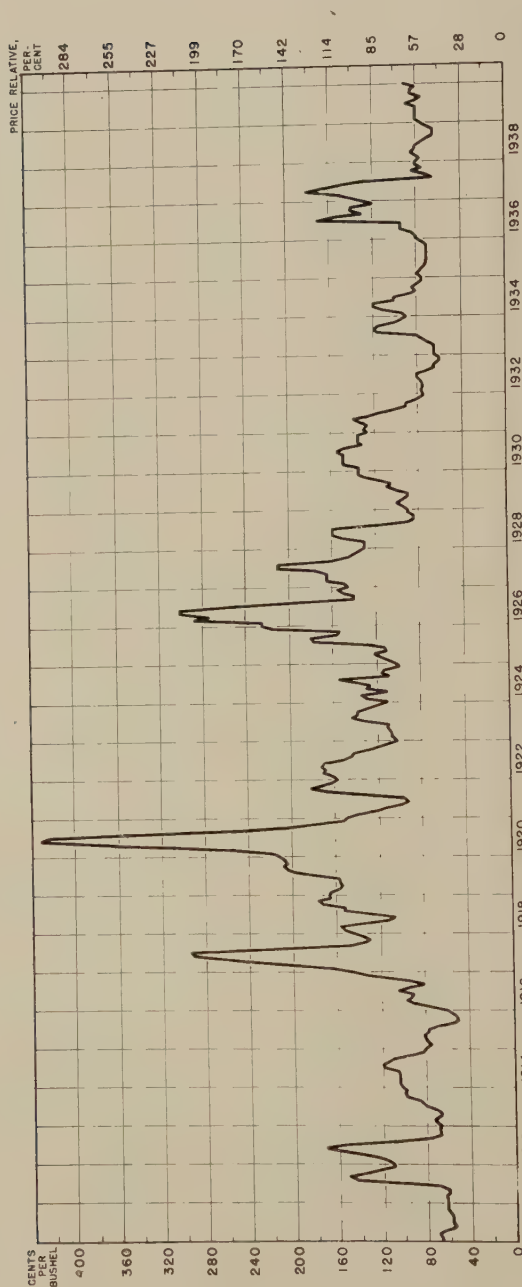


Figure 6. Potatoes. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices were very irregular and showed a gradual downward trend after 1920. Major marketings of potatoes occur in July, August and September in this state and prices during these months are more indicative of those received by producers than the prices in other months. This chart and also that for apples is drawn on a price relative scale of one-third less than the other charts.

Table 11. Potatoes. Prices received by Kentucky producers on the 15th of the month, 1939¹ (cents per bushel).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
68	70	66	58	55	58	58	58	58	60	62	62	62	59
62	64	61	61	69	100	145	152	137	124	110	110	110	144
114	124	141	160	174	152	108	76	66	68	67	66	66	86
72	73	66	66	72	80	83	88	98	100	98	103	87	87
104	104	104	104	106	118	120	114	108	92	82	80	114	114
75	78	81	82	78	78	68	54	50	52	57	60	58	58
76	90	96	92	90	104	94	80	93	116	136	145	86	86
162	205	242	267	291	294	226	150	134	130	136	144	171	171
152	156	136	112	106	128	152	154	172	178	165	166	156	156
164	156	154	156	158	181	198	204	209	205	206	211	201	201
222	250	304	380	432	422	350	257	204	174	152	150	275	275
138	123	113	99	92	96	124	164	184	172	162	158	154	154
162	170	168	172	169	151	144	142	128	120	110	102	141	141
107	107	108	112	110	130	144	138	138	128	120	111	138	138
130	135	110	130	125	140	155	108	115	113	99	101	122	122
108	115	122	111	113	132	177	180	157	153	215	225	173	173
224	237	275	300	300	260	210	140	140	150	155	145	164	164
150	165	165	165	175	210	210	160	145	140	135	130	171	171
130	130	150	160	160	160	120	90	85	85	90	90	99	99
95	100	95	90	90	100	110	105	115	130	135	135	108	108
135	150	150	150	150	155	150	130	135	135	135	125	137	137
130	125	130	140	125	115	100	90	90	80	75	75	94	94
76	75	76	77	80	80	70	65	65	60	60	65	67	67
65	65	65	70	75	80	115	120	115	100	95	90	115	115
95	110	120	120	100	100	85	80	85	80	75	75	84	84
80	78	75	72	70	70	70	70	70	70	75	80	70	70
80	85	95	95	95	170	155	130	140	140	120	130	136	136
140	155	180	165	150	125	65	70	85	75	80	80	75	75
75	80	85	80	80	75	65	65	65	65	70	75	66	66
80	80	80	80	80	90	80	75	85	85	80	90	78	78

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 12. Potatoes. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
48	50	47	41	39	41	41	41	43	44	44	44	42	42
44	45	43	43	49	71	103	108	97	88	78	78	102	102
81	88	100	113	123	108	77	54	47	48	48	47	61	61
51	52	47	47	51	57	59	62	70	71	70	73	62	62
74	74	74	74	75	84	85	81	77	65	58	57	81	81
53	55	57	58	55	55	48	38	35	37	40	43	41	41
54	64	68	65	64	74	67	57	66	82	96	103	61	61
115	145	172	189	206	209	160	106	95	92	96	102	121	121
108	111	96	79	75	91	108	109	122	126	117	118	111	111
116	111	109	111	112	128	140	145	148	145	146	150	143	143
157	177	216	270	306	299	248	182	145	123	108	106	195	195
98	87	80	70	65	68	88	116	130	122	115	112	109	109
115	121	119	122	120	107	102	101	91	85	78	72	106	106
76	76	77	79	78	92	102	98	98	91	85	79	98	98
92	96	78	92	89	99	110	77	82	80	70	72	87	87
77	82	87	79	80	94	126	128	111	109	152	160	123	123
159	204	195	213	213	184	149	99	99	106	110	103	116	116
106	117	117	117	124	149	149	113	103	99	96	92	121	121
92	92	106	113	113	113	85	64	60	60	64	64	70	70
67	71	67	64	64	71	78	74	82	92	96	96	77	77
96	106	106	106	106	110	106	92	96	96	96	89	97	97
92	89	92	99	89	82	71	64	64	57	53	53	67	67
54	53	54	55	57	57	50	46	46	43	43	46	48	48
46	46	46	50	53	57	82	85	82	71	67	64	32	32
67	78	85	85	71	71	60	57	60	57	53	53	60	60
57	55	53	51	50	50	50	50	50	50	53	57	50	50
57	60	67	67	67	121	110	92	99	99	85	92	96	96
99	109	128	117	106	89	46	50	60	53	57	57	53	53
53	57	60	57	57	53	46	46	46	46	50	53	47	47
57	57	57	57	57	64	57	53	60	60	57	64	55	55

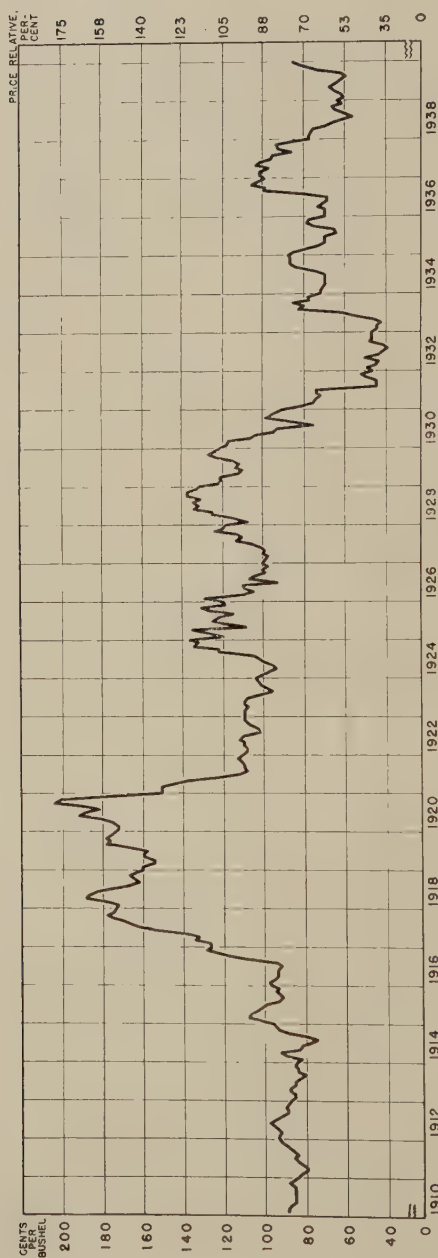


Figure 7. Rye. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Compared with prices that prevailed in the twenties, rye prices during the war rose less than the other grain prices. Rye is relatively unimportant as a grain crop in this state and the monthly prices are averages of a rather small number of price quotations. The general movement of prices is more significant than the price for any one month.

Table 13. Rye. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per bushel).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
89	89	88	86	85	86	86	86	86	86	88	87	84	86
82	80	80	82	84	84	85	84	86	88	90	92	94	87
94	92	93	96	98	96	96	92	89	89	90	89	88	90
85	85	88	88	85	86	86	83	80	84	84	85	84	83
82	90	92	83	82	79	74	80	89	89	94	95	96	84
101	108	107	104	102	99	94	91	92	95	94	97	94	94
98	95	94	93	94	91	94	108	116	122	129	126	109	109
127	134	132	138	154	162	166	170	176	178	174	176	169	169
172	178	188	187	182	175	166	162	165	166	164	160	166	166
160	154	154	160	160	158	168	178	177	178	176	173	173	173
172	172	174	180	191	189	181	190	204	200	168	150	188	188
150	150	144	134	122	112	108	110	110	111	113	111	112	112
108	108	110	109	112	109	101	103	106	108	110	109	105	105
110	110	108	110	110	108	101	96	99	102	103	104	100	100
100	98	93	96	100	103	105	122	122	135	132	137	119	119
120	126	136	108	118	125	122	115	126	131	118	120	122	122
130	109	105	110	111	93	107	104	99	100	98	100	104	104
99	98	100	99	101	106	114	111	113	124	120	119	114	114
107	115	125	125	135	132	135	131	138	138	133	131	133	133
122	121	121	112	111	114	112	115	123	128	124	121	118	118
117	117	106	104	95	93	75	89	98	97	94	90	90	90
81	75	74	72	74	74	45	45	45	50	53	47	49	49
49	45	43	50	43	41	39	41	48	47	47	47	43	43
44	45	42	46	56	61	83	80	86	78	78	72	78	78
72	71	69	70	70	70	74	83	87	87	87	88	81	81
84	79	73	69	69	69	64	65	75	79	78	69	70	70
69	70	73	71	68	68	80	99	99	106	103	99	93	93
102	102	97	104	102	96	95	85	92	94	87	78	91	91
78	76	75	70	66	61	56	60	65	66	61	64	62	62
60	61	65	67	64	61	59	61	73	78	82	85	67	67

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 14. Rye. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
78	78	77	75	75	75	75	75	75	75	77	76	74	75
72	70	70	72	74	75	74	75	77	79	81	82	82	76
82	81	82	84	86	84	81	78	78	79	78	77	79	79
75	75	77	77	75	75	73	70	74	74	75	74	73	73
72	79	81	73	72	69	65	70	78	82	83	84	74	74
89	95	94	91	89	87	82	80	81	83	82	85	82	82
86	83	82	82	82	80	82	95	102	107	113	111	96	96
111	118	116	121	135	142	146	149	154	156	153	154	148	148
151	156	165	164	160	154	146	142	145	146	144	140	146	146
140	135	135	140	140	139	147	156	155	156	154	152	152	152
151	151	153	158	168	166	159	167	179	175	147	132	165	165
132	132	126	118	107	98	95	96	96	97	99	97	98	98
95	95	96	96	98	96	96	89	90	93	95	96	92	92
96	96	95	96	96	95	95	89	84	87	89	90	91	88
88	86	82	84	88	88	90	92	107	107	118	116	120	104
105	111	119	95	104	110	107	101	111	115	104	105	107	107
114	96	92	96	97	82	94	91	87	88	86	88	91	91
87	86	88	87	89	93	100	97	99	109	105	104	100	100
94	101	110	110	118	116	118	115	121	121	117	115	117	117
107	106	106	98	97	100	98	101	108	112	109	106	104	104
103	103	93	91	83	82	66	78	86	85	82	79	79	79
71	66	65	63	65	65	39	39	39	44	46	41	43	43
43	39	38	44	38	36	34	36	42	41	41	41	38	38
39	39	37	40	49	54	73	70	75	68	68	63	68	68
63	62	61	61	61	61	65	73	76	76	76	77	71	71
74	69	64	61	61	61	61	57	66	69	68	61	61	61
61	61	64	62	60	60	60	70	87	93	90	87	82	82
89	89	85	91	89	84	83	75	81	82	76	68	80	80
68	67	66	61	58	54	49	53	57	58	54	56	54	54
53	54	57	59	56	54	52	54	64	68	72	75	59	59

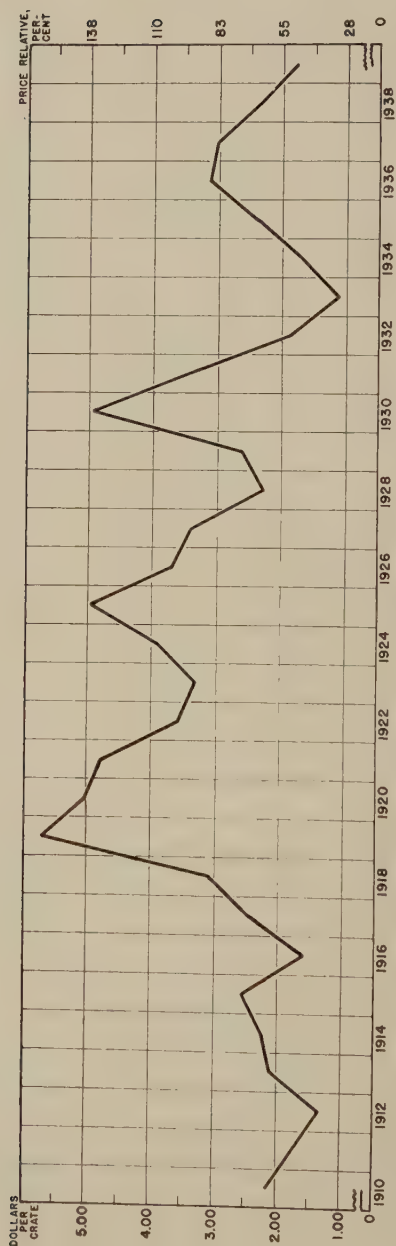


Figure 8. Strawberries. Season average prices received by strawberry marketing associations in Kentucky, 1910-1939, and corresponding relatives of prices. (For price relatives, season average prices, 1921-1929 = 100.)

For strawberries the season average prices were charted in preference to monthly prices. Peak prices occurred at rather regular intervals, from five to six years apart, but the trend of prices since 1919 has been gradually downward.

Table 15. Strawberries. Prices received by strawberry marketing associations in Kentucky, 1919-1939¹ (dollars per 24-quart crate).

Year	May	June	Season average
1910	2.33	2.10	2.15
1911	1.90	1.71	1.75
1912	1.46	1.32	1.35
1913	2.28	2.05	2.10
1914	2.44	2.19	2.25
1915	2.76	2.49	2.55
1916	1.73	1.56	1.60
1917	2.67	2.40	2.46
1918	3.36	3.02	3.10
1919	6.23	5.61	5.75
1920	5.47	4.92	5.05
1921	5.20	4.68	4.80
1922	3.90	3.51	3.60
1923	3.63	3.27	3.35
1924	3.73	4.00	3.91
1925	4.97	4.84	4.96
1926	5.28	3.34	3.70
1927	3.41	3.41	3.41
1928	2.45	2.24	2.28
1929	2.63	2.63	2.63
1930	4.95	3.71	4.92
1931	4.01	2.98	3.43
1932	2.00	1.39	1.85
1933	1.15	.98	1.14
1934	1.67	2.07	1.70
1935	2.52	1.96	2.39
1936	3.11	2.04	3.11
1937	3.22	2.64	3.03
1938 ²	2.33		2.33
1939	1.84	1.25	1.77

¹ Prices are f.o.b. shipping point and therefore include local handling and selling costs.

² A few sales were made in April, 1938, but none in June.

Table 16. Strawberries. Relatives of prices received by strawberry marketing associations in Kentucky, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	May	June	Season average
1910	64	58	59
1911	52	47	48
1912	40	36	37
1913	63	56	58
1914	67	60	62
1915	76	69	70
1916	48	45	44
1917	74	66	68
1918	93	83	85
1919	172	155	158
1920	151	138	139
1921	143	129	132
1922	107	97	99
1923	100	90	92
1924	103	110	108
1925	137	133	137
1926	145	92	102
1927	94	94	94
1928	67	62	63
1929	72	72	72
1930	136	102	136
1931	110	82	94
1932	55	38	51
1933	32	27	31
1934	46	57	47
1935	69	54	66
1936	86	56	86
1937	89	73	83
1938	64		64
1939	51	31	49

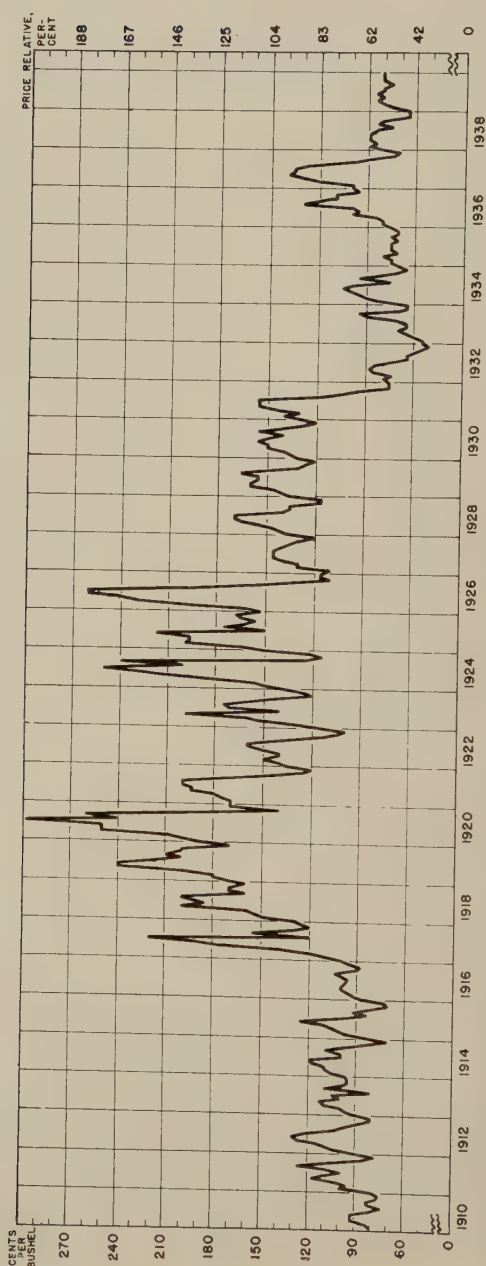


Figure 9. Sweetpotatoes. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Evidence of a definite seasonal price pattern is observable in most years, lowest prices occurring usually in October and November and highest prices in the late spring or early summer. Considerable variation has taken place in prices within the same year and from year to year. Prices of sweetpotatoes in the middle twenties were relatively higher than those of many farm products.

Table 17. Sweetpotatoes. Prices received by Kentucky producers on the 15th of the month, 1910-1939¹ (cents per bushel).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
81	84	92	92	92	80	74	82	82	76	75	80	81
100	95	102	117	109	98	109	127	102	85	78	91	96
104	110	114	125	130	120	103	98	91	80	80	91	96
97	100	109	112	100	105	80	110	100	95	95	96	100
105	110	110	116	120	100	100	110	98	85	71	85	95
95	100	105	110	125	100	84	92	80	70	72	86	87
92	95	100	100	96	95	100	104	90	88	95	100	94
110	120	140	175	190	220	120	155	130	120	125	130	135
150	155	160	200	185	195	200	160	170	170	160	170	168
180	180	200	240	240	220	200	210	200	200	170	190	197
200	210	250	250	250	300	240	260	200	139	170	170	196
170	175	180	195	195	200	200	170	150	125	120	135	152
140	150	140	140	150	160	160	140	115	105	100	115	123
130	152	160	197	140	170	175	160	142	119	124	135	140
150	155	185	210	230	250	200	240	125	114	123	150	152
164	200	197	197	217	150	175	163	155	165	168	152	171
163	205	230	240	260	260	200	160	130	110	115	115	155
110	130	130	140	146	145	145	140	135	130	120	135	131
140	145	155	165	170	170	140	135	135	115	115	135	135
140	145	160	160	155	155	165	145	130	125	120	130	136
135	140	150	150	155	150	140	155	140	130	120	130	137
140	130	145	155	155	155	120	105	95	75	75	75	104
79	74	85	88	85	75	65	65	60	55	50	55	65
55	60	65	70	65	65	70	90	95	70	65	65	70
80	90	95	100	105	100	75	95	80	70	65	70	80
75	75	80	70	75	75	75	70	75	70	70	75	73
80	80	85	100	95	100	130	120	110	110	95	100	100
100	120	130	140	135	135	125	100	90	75	70	80	96
90	85	90	90	90	85	75	85	80	65	65	65	77
75	80	85	85	85	80	80	75	80	80	80	80	80

¹Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

²For calendar year, weighted by average monthly marketings of 1926-1930.

Table 18. Sweetpotatoes. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
56	58	64	64	64	56	51	57	57	53	52	56	56
69	66	71	81	76	68	76	88	71	59	54	63	67
72	76	79	87	90	83	72	68	63	56	56	63	67
67	69	76	78	69	73	56	76	69	66	66	67	69
73	76	76	81	83	69	69	76	68	59.	49	59	66
66	69	73	76	87	69	58	64	56.	49	50	60	60
64	66	69	69	67	66	69	72	62	61	66	69	65
76	83	97	122	132	153	83	108	90	83	87	90	94
104	108	111	139	128	135	139	111	118	118	111	118	117
125	125	139	167	167	153	139	146	139	139	118	132	137
139	146	174	174	174	208	167	181	139	97	118	118	136
118	122	125	135	135	139	139	118	104	87	83	94	106
97	104	97	97	104	111	111	97	80	73	69	80	85
90	106	111	137	97	118	122	111	99	83	86	94	97
104	108	128	146	160	174	139	167	87	79	85	104	106
114	139	137	137	151	104	122	113	108	115	117	106	119
113	142	160	167	181	181	139	111	90	76	80	80	108
76	90	90	97	101	101	101	97	94	90	83	94	91
97	101	108	115	118	118	97	94	94	80	80	94	94
97	101	111	111	108	108	115	101	90	87	83	90	94
94	97	104	104	108	104	97	108	97	90	83	90	95
97	90	101	108	108	108	83	73	66	52	52	52	72
55	51	59	61	59	52	45	45	42	38	35	38	45
38	42	45	49	45	45	49	62	66	49	45	45	49
56	62	66	69	73	69	52	66	56	49	45	49	56
52	52	56	49	52	52	52	49	52	49	49	52	51
56	56	59	69	66	69	90	83	76	76	66	69	69
69	83	90	97	94	94	87	69	62	52	49	56	67
62	59	62	62	62	59	52	59	56	45	45	45	53
52	56	59	59	59	56	56	52	56	56	56	56	56

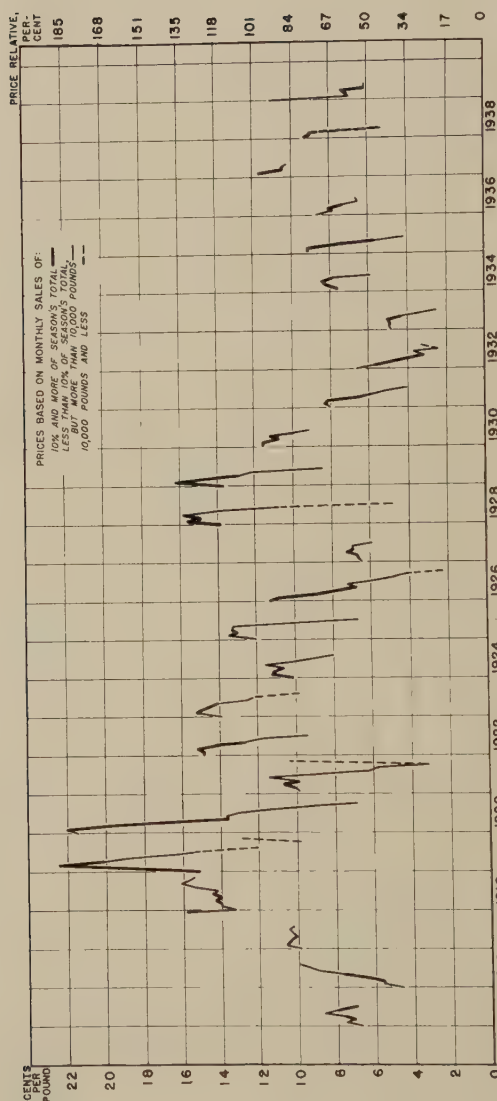


Figure 10. Tobacco, type 22 (Eastern fire-cured). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1914-1938. (For price relatives, average crop-year prices, 1920-1929 = 100.)

Tobacco is not marketed continuously but only during a relatively short marketing season. Monthly prices usually either decline thruout the season or rise for a time and then decline. A decided shortening of the season is noticeable.

Table 19. Tobacco, type 22 (Eastern fire-cured). Prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (cents per pound).

For be- ginning Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wd. av- erage
1												8.00
2												8.80
3												9.00
4												7.80
5												9.00
6	6.72	7.62	7.18	7.55	8.68	7.97	6.99					7.50
7	4.53	5.54	5.70	6.38	7.64	8.90	9.37	10.03				6.50
8	9.88	10.58	10.52	10.42	10.15	10.44	10.51	10.29				10.44
9	15.87*	13.30	13.97	14.05	14.42	13.38	14.46	14.26	15.40	16.21	15.65	15.42
10	15.26	19.12	22.51	20.17	19.00	16.52	15.49	12.08*			9.89	12.90*
11	21.45	22.11	19.44	17.02	13.67	13.59	13.15	11.67	9.22	6.91		16.87
12		9.87	10.15	10.75	9.86	11.50	8.68	6.29	5.74	3.14	10.33*	10.23
13	14.88	14.80	15.21	14.30	12.68	11.81	9.42					14.44
14	13.92	15.25	14.97	14.48	14.18	12.57	12.15	9.81*				14.59
15	12.02	11.22	11.16	10.64	11.64	10.00	8.87	8.07				10.65
16	12.09	13.56	13.08	13.22	13.28	10.78	6.71					13.10
17	11.31	10.85	8.89	7.79	6.72	7.24	5.91	4.85	4.20	2.32*		8.55
18		6.68	6.78	7.22	6.99	7.01	5.97					6.95
19	13.74	15.57	15.00	15.77	14.04	10.73	4.86*					15.06
20	13.68	16.12	14.88	12.88	12.17	8.50						14.18
21	11.57	11.60	10.76	11.26	10.04	9.17						11.17
22	8.05	8.27	8.25	6.49	5.81	5.37	4.12					7.42
23	6.61	5.72	4.80	4.05	3.13	3.71	2.36	3.31*				4.56
24	4.78	4.98	4.98	5.07	4.38	3.40	2.51					4.88
25		7.56	8.11	8.45	7.93	5.86						8.04
26		9.18	9.14	7.49	5.81	4.20						8.31
27	8.74	7.82	8.09	7.39	6.53	6.64						7.72
28		11.66	10.48	10.52	10.25							10.76
29		9.34	9.08	9.02	5.27*							9.17
30	11.05	7.04	7.08	7.41	6.20	6.12						7.11

Annual prices for 1909-1915 are for the entire production of this type and are taken from Circular 249, "Tobacco Types, Uses and Markets," U. S. Department of Agriculture. No data on monthly prices for 1909-1913 are available. The crop-year average price for 1914 is distributed seasonally according to sales of fire-cured tobacco on the Hopkinsville market, and that for 1915 according to all sales of fire-cured tobacco in Kentucky, as reported to the Commissioner of Agriculture. Monthly prices for 1916-1938 are calculated from warehouse reports to the Commissioner of Agriculture of Kentucky.

Based upon sales of less than 10,000 pounds.

Table 20. Tobacco, type 22 (Eastern fire-cured). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (average crop year prices, 1920-29 = 100).

For be- ginning Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wd. av- erage
1												67
2												74
3												76
4												66
5												76
6												63
7	57	64	60	63	73	67	58					55
8	38	47	48	54	64	75	79	84				88
9	83	89	88	88	85	88	88	87				130
10	131*	112	117	118	121	118	122	120	130	136	132	108*
11	128	161	189	170	160	139	130	102*			83	87*
12	180	186	163	143	115	114	111	98	78	58		
13		83	85	90	83	97	73	53	48	26		
14	125	124	128	120	107	99	79					
15	117	128	126	122	119	106	102	83*				
16	84	94	94	39	98	84	75	68				
17	102	114	110	111	112	91	56					
18	95	91	75	66	57	61	50	41	35	20*		
19		56	57	61	59	59	50					
20	116	131	126	133	118	90	41*					
21	115	136	125	108	102	71						
22		97	98	90	95	84	77					
23		68	70	69	55	49	45	35				
24		56	48	40	34	26	31	20	28*			
25		40	42	42	43	37	29	21				
26		64	68	71	67	49						
27		77	77	63	49	35						
28		74	66	68	62	55	56					
29			98	88	88	86						
30			79	76	76	44*						
31		93	59	60	62	52	51					

Based upon sales of less than 10,000 pounds.

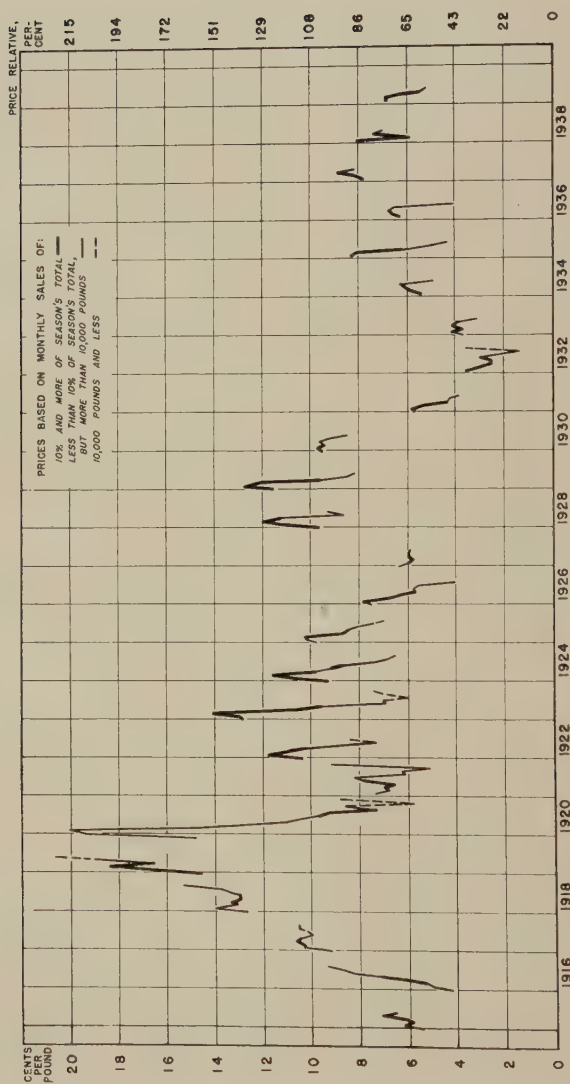


Figure 11. Tobacco, type 23 (Western fire-cured). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1914-1938. (For price relatives, average crop-year prices, 1920-1929 = 100.)

Tobacco is not marketed continuously but only during a relatively short marketing season. Monthly prices usually either decline thruout the season or rise for a time and then decline. A decided shortening of the season is noticeable.

Table 21. Tobacco, type 23 (Western fire-cured). Prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (cents per pound).

begin- ing Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wt. av- erage	
1												7.30	
												7.80	
												8.00	
												6.20	
												7.70	
	5.47	6.20	5.84	6.14	7.06	6.48						6.10	
	4.19	5.12	5.27	5.89	7.05	8.21	8.65	9.26				6.00	
	9.18*	10.28	10.30	10.61	10.43	10.01	10.19	10.50*	10.50*			10.44	
	12.69	14.10	13.03	13.36	12.91	12.93	13.41	13.72	15.37			13.12	
	14.52	16.61	18.43	16.49	19.06	21.10*						16.93	
	14.79	19.33	20.16	14.67	12.42	10.91	10.32	9.65	9.26	7.31	8.58	5.76*	12.06
	8.84*		7.36	6.76	7.04	6.47	7.81	8.28	6.16	6.20	5.06	9.17	6.91
	10.30	11.76	10.78	10.30	9.18	7.30	8.43*						10.46
	12.82	12.94	14.08	10.80	9.62	6.91	7.00*	6.00*	6.85*	7.42*			12.17
	9.34	10.63	11.58	9.74	9.21	8.81	7.51	6.77	6.51				9.68
	9.80	10.17	10.27	8.58	8.45	8.09	7.40	7.00*					9.32
	7.52	7.82	6.72	6.19	5.63	5.79	5.54	4.04					6.45
	6.34	5.95	5.77	5.93	5.90	5.89							5.88
	9.68	11.16	11.96	11.21	8.60	9.25							11.19
	11.53	12.73	12.07	9.53	8.41	8.12							11.32
	9.46	9.70	9.43	9.56	9.16	8.45							9.54
	5.61	5.74	5.29	4.34	4.24	3.81							5.19
		3.53	3.01	2.52	2.48	2.99	2.22	1.30	3.50*				2.92
	3.67	4.12	3.63	4.15	3.95	3.05							3.93
		5.33	5.89	6.08	6.20	4.84							5.81
		8.23	8.07	5.85	5.01	4.29							7.54
		6.23	6.57	6.73	6.50	4.03							6.49
		7.72	8.01	8.81	8.18								8.08
		8.05	5.81	7.41	7.01								7.80
		6.83	6.80	6.41	5.41	5.20							6.43

Annual prices for 1909-1915 are for the entire production of this type and are taken from Circular 249, "Tobacco Types, Uses and Markets," U. S. Department of Agriculture. No data on monthly prices for 1909-1913 are available. The crop-year average price for 1914 is distributed seasonally according to sales of fire-cured tobacco on the Hopkinsville market, and for 1915 according to all sales of fire-cured tobacco in Kentucky, as reported to the Commissioner of Agriculture. Monthly prices for 1916-1938 are calculated from warehouse receipts to the Commissioner of Agriculture of Kentucky.

* Based upon sales of less than 10,000 pounds.

Table 22. Tobacco, type 23 (Western fire-cured). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1914-1928 (average crop year prices, 1920-1929 (100)).

Our be- ginning Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wt. av- erage	
7. 1													
9												79	
0												84	
1												86	
2												67	
3												83	
4	59	67	63	66	76	70						66	
5	45	55	57	63	76	88	93	100				65	
6	99*	111	111	114	112	108	110	113*	113*			112	
7	137	152	140	144	139	139	144	148	165			141	
8	156	179	198	178	205	227*						182	
9	159	208	217	158	134	117	111	104	100	79	92	62*	130
0	95*		79	73	76	70	84	89	66	67	54	99	74
1		111	127	116	111	99	79	91*					113
2		138	139	152	116	104	74	75*	65*	74*	80*		131
3		101	114	125	105	99	95	81	73	70			104
4		105	109	111	92	91	87	80	75*				100
5		81	84	72	67	61	62	60	43				69
6		68	64	62	64	64	63						63
7		104	120	129	121	93	100						120
8		124	137	130	103	91	87						122
9		102	104	102	103	99	91						103
0		60	62	57	47	46	41						56
1			38	32	27	27	32	24	14	38*			31
2		40	44	39	45	43	33						42
3			57	63	65	67	52						63
4			89	87	63	54	46						81
5			67	71	72	70	43						70
6			83	86	95	88							87
7			87	63	80	75							84
8			74	73	69	58	56						69

* Based upon sales of less than 10,000 pounds.

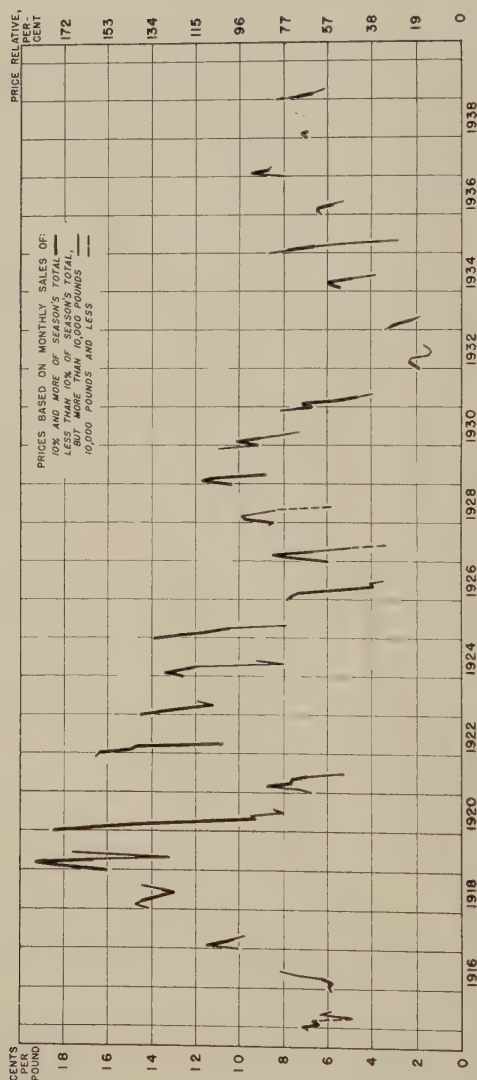


Figure 12. Tobacco, type 24 (Henderson fire-cured). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1914-1938. (For price relatives, average crop-year prices, 1920-1929 = 100.)

Tobacco is not marketed continuously but only during a relatively short season. Monthly prices usually either decline thruout the season or rise for a time and then decline. A decided shortening of the season is noticeable.

Table 23. Tobacco, type 24 (Henderson fire-cured). Prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (cents per pound).

Year beginning Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
1909													6.99
1910													7.07
1911													8.05
1912													6.81
1913													6.60
1914		7.25	6.41	6.71	4.87	6.41	5.84						6.50
1915	5.87	6.00	5.92	5.86	6.41	7.45	8.13						6.10
1916		10.09	11.48	10.62	10.29	9.78							10.89
1917		14.17	14.80	14.53	14.08	13.58	13.02	13.45	14.45				13.81
1918		15.98	17.86	19.33	16.62	13.23	17.67						17.13
1919		18.46	16.87	14.95	11.64	9.28	9.36	8.06	8.52				14.04
1920		6.67	7.36	8.76	7.64	7.67	6.94	5.26					7.71
1921	16.51	16.40	14.94	14.77	10.76								14.99
1922	14.25	14.51	13.43	12.38	11.14	11.95							13.17
1923		12.58	13.44	12.76	12.03	8.00	9.35						12.53
1924		13.87	12.77	11.33	10.45	7.81							12.17
1925		7.89	7.62	7.34	5.57	3.99	4.12	3.43					6.59
1926		5.93	7.60	8.46	6.71	4.90	3.33*						7.47
1927	8.66	8.48	9.71	9.93	8.96	8.36	5.82*						9.49
1928		10.39	11.69	11.17	8.79								10.91
1929	10.94	9.21	10.18	9.07	8.10	7.32							9.49
1930	8.14	6.72	7.23	5.56	4.68	3.94							6.15
1931		1.86	2.21	2.43	2.35	1.50	1.32	1.47	1.72				2.18
1932		3.47	3.29	2.76	2.23	1.89							2.90
1933			5.45	5.92	6.01	4.96	3.87						5.69
1934		8.65	7.80	6.68	5.14	2.84							7.17
1935		6.30	6.48	6.44	5.71	5.34							6.11
1936		8.11	9.55	8.71	8.54								9.17
1937		6.96	7.24	6.90									7.14
1938		8.34	7.45	6.70	6.21								7.08

Annual prices for 1909-1913 were furnished by buyers of Green River tobacco but data not available from which monthly prices can be estimated. Annual prices for 1914 and 1915 estimated from the price of type 36, and are distributed seasonally according to sales of Green River tobacco in Kentucky. Monthly prices for 1916-1938 are calculated from warehouse reports to the Kentucky Commissioner of Agriculture.

*Based upon sales of less than 10,000 pounds.

Table 24. Tobacco, type 24 (Henderson fire-cured). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (average crop year price, 1920-29 = 100).

Year beginning Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Crop-year wtd. average
1909										67
1910										68
1911										77
1912										65
1913										63
1914		69	61	64	47	61	57			62
1915	56	57	57	56	61	71	78			58
1916		97	110	102	98	94				104
1917		136	142	139	135	130	125	129	138	132
1918		153	171	185	159	127	169			164
1919		177	161	143	111	89	90	77	82	134
1920		64	70	84	73	73	66	50		74
1921	158	157	143	141	103					143
1922	136	139	129	118	107	114				126
1923		120	129	122	115	77	89			120
1924		133	122	108	100	75				116
1925		76	73	70	53	38		33		63
1926		57	73	81	64	47	32*			71
1927	83	81	93	95	86	80	56*			91
1928		99	112	107	84					104
1929	105	88	97	87	78	70				91
1930	78	64	69	53	45	38				59
1931		18	21	23	22	14	13	14	16	21
1932		33	31	26	21	18				28
1933			52	57	58	47	37			54
1934		83	75	64	49	27				69
1935		60	62	62	55	51				58
1936		78	91	83	82					88
1937		67	69	66						68
1938		80	71	64	59					68

*Based upon sales of less than 10,000 pounds.

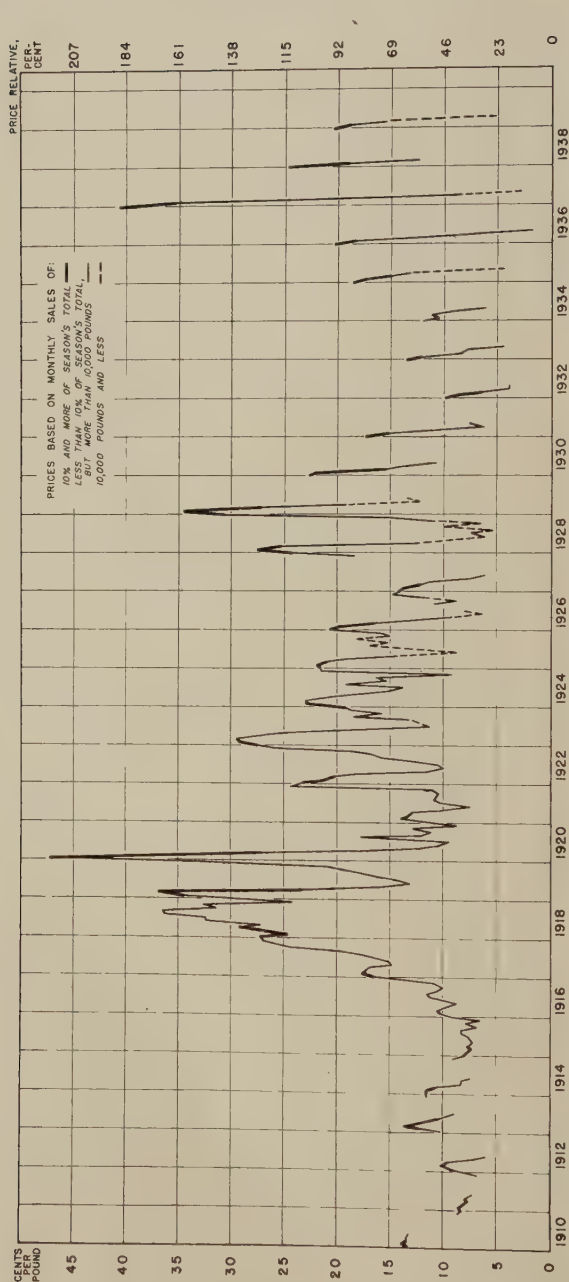


Figure 13. Tobacco, type 31 (Burley). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1909-1938. (For price relatives, average crop-year prices, 1920-1929 = 100.)

During part of the period shown, a year-around market was maintained for Burley tobacco but the heaviest sales occurred in a rather short season. During recent years monthly prices usually have fallen thruout the season but in the earlier years prices were inclined to rise for one or two months at the beginning of the season. Burley prices are higher, relative to prewar prices, than prices of most farm products.

Table 25. Tobacco, type 31 (Burley). Prices paid for growers' sales in Kentucky warehouses, by months, 1909-1938 (cents per pound).

Crop year ending Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
1909	12.87	13.41	13.93	13.51	13.38	13.32	.....	.....	.....	.....	.....	.....	13.40
1910	8.83	8.66	8.89	8.12	7.52	7.83	7.24	.....	.....	.....	.....	.....	8.20
1911	6.78	7.96	9.31	10.28	9.46	7.21	5.76	.....	.....	.....	.....	.....	9.30
1912	9.95	11.76	13.43	11.47	9.93	8.77	.....	.....	.....	.....	.....	.....	12.00
1913	11.62	11.44	11.61	10.63	8.32	8.16	7.31	.....	.....	.....	.....	.....	11.10
1914	8.85*	8.12	7.66	7.47	7.70	7.26	7.45	7.69	8.23	8.16	6.83	7.79	7.66
1915	6.62	9.21	10.20	10.40	9.67	8.61	9.98	11.13	11.59	10.34	9.96	10.62	10.15
1916	12.70	16.31	17.65	17.37	16.74	14.87	14.89	16.56	17.41	19.45	24.11	25.75	17.24
1917	26.78	27.05	24.34	26.47	29.02	27.10	32.44	32.44	36.30	36.39	31.28	32.59	26.69
1918	24.11	28.15	34.41	36.74	22.99	15.82	13.14	14.19	15.03	17.48	18.68	20.62	32.46
1919	31.51	47.23	37.86	26.93	17.82	11.84	10.48	9.43	17.68	11.86	11.17	12.81	34.23
1920	8.64	11.04	13.85	13.17	12.80	9.79	7.45	10.02	10.86	10.71	10.40	10.88	13.12
1921	24.38	23.19	21.27	20.10	17.91	11.24	10.07	10.39	12.87	15.94	16.68	18.71	21.35
1922	25.95	27.31	29.04	29.23	27.13	24.15	17.30	11.04	12.14*	13.00*	18.44	15.71	28.25
1923	18.62	19.14	22.73	22.89	20.70	17.36	14.94	13.70	19.04	15.12	16.21	9.05	21.49
1924	21.56	21.49	21.76	20.87	19.18	14.43	8.67*	13.29*	17.00*	15.26*	18.05*	14.92	21.29
1925	15.93	20.56	19.71	16.55	12.37	9.07	6.23*	8.00*	.....	10.76	8.78	11.88*	18.86
1926	14.83	14.01	13.64	12.15	11.06	7.46	6.11	.....	.....	.....	.....	.....	13.12
1927	18.20	24.10	27.41	25.16	12.32	9.41*	6.16*	7.44	5.47*	9.82*	6.55*	10.88*	26.06
1928	15.19	30.65	34.50	27.12	19.05	12.25*	13.22*	.....	.....	.....	.....	.....	32.18
1929	.....	22.61	21.95	15.40	13.73	10.70	.....	.....	.....	.....	.....	.....	21.34
1930	.....	17.07	15.09	9.50	6.02	7.42	.....	.....	.....	.....	.....	.....	15.18
1931	.....	9.78	8.59	6.35	3.97	3.91	.....	.....	.....	.....	.....	.....	8.59
1932	.....	13.54	12.04	8.15	7.71	4.38	.....	.....	.....	.....	.....	.....	12.16
1933	.....	11.93	10.45	11.08	9.19	5.98	3.59	.....	.....	.....	.....	.....	10.67
1934	.....	18.48	17.48	14.91	13.04	4.24*	.....	.....	.....	.....	.....	.....	17.46
1935	.....	20.16	18.20	11.67	6.92	1.73*	.....	.....	.....	.....	.....	.....	18.83
1936	.....	40.68	35.08	20.19	8.64	2.83*	.....	.....	.....	.....	.....	.....	35.70
1937	.....	24.52	18.91	12.46	.....	.....	.....	.....	.....	.....	.....	.....	20.46
1938	.....	20.34	18.99	15.43	5.65*	.....	.....	.....	.....	.....	.....	.....	19.60

Prices for the crop years 1909-1913 are Kentucky farm prices estimated on the basis of newspaper reports of sales in Lexington and in from one to six other burley markets. These crop-year prices are distributed seasonally according to sales in Lexington. For 1914 and 1915 prices are from monthly reports of the Commissioner of Agriculture of Kentucky. Monthly prices for 1916-1938 are calculated from warehouse reports to the Kentucky Commissioner of Agriculture.

*Based upon sales of less than 10,000 pounds.

Table 26. Tobacco, type 31 (Burley). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1909-1938 (average crop-year prices, 1920-1929 = 100).

Crop year ending Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
1909	59	62	64	62	62	61	.....	.....	.....	.....	.....	.....	62
1910	41	40	41	37	35	36	33	.....	.....	.....	.....	.....	38
1911	31	37	43	47	44	33	27	.....	.....	.....	.....	.....	43
1912	46	54	62	53	46	40	.....	.....	.....	.....	.....	.....	55
1913	54	53	53	49	38	38	34	.....	.....	.....	.....	.....	51
1914	41*	37	35	34	35	33	34	35	38	38	31	36	35
1915	30	42	47	48	45	40	46	51	53	48	46	49	47
1916	58	75	81	80	77	68	69	76	80	90	111	119	79
1917	123	125	112	122	134	125	149	149	167	168	144	150	123
1918	111	120	158	169	106	73	61	65	74	81	86	95	150
1919	145	218	174	124	82	55	48	43	81	55	51	59	158
1920	40	51	64	61	59	45	34	46	50	49	48	50	60
1921	112	107	98	93	82	52	46	48	59	73	77	86	98
1922	120	126	134	135	125	111	80	51	56*	60*	85	72	120
1923	86	88	105	105	95	80	69	63	88	70	75	42	99
1924	99	99	100	96	88	66	40*	61*	78*	70*	83*	69	98
1925	73	95	91	76	57	42	29*	37*	.....	50	40	55*	87
1926	68	65	63	56	51	34	28	.....	.....	.....	.....	.....	60
1927	84*	111	126	116	57	43*	28*	34	25*	45*	30*	50*	120
1928	70	141	159	125	88	56*	61*	.....	.....	.....	.....	.....	148
1929	.....	104	101	71	68	49	.....	.....	.....	.....	.....	.....	98
1930	.....	79	70	44	28	34	.....	.....	.....	.....	.....	.....	70
1931	.....	45	40	29	18	18	.....	.....	.....	.....	.....	.....	40
1932	.....	62	55	38	36	20	.....	.....	.....	.....	.....	.....	56
1933	.....	55	48	51	42	28	.....	.....	.....	.....	.....	.....	49
1934	.....	85	81	69	60	20*	.....	.....	.....	.....	.....	.....	80
1935	.....	93	84	54	32	8*	.....	.....	.....	.....	.....	.....	87
1936	.....	187	162	93	40	13*	.....	.....	.....	.....	.....	.....	164
1937	.....	113	87	57	.....	.....	.....	.....	.....	.....	.....	.....	94
1938	.....	94	87	71	26*	.....	.....	.....	.....	.....	.....	.....	90

*Based upon sales of less than 10,000 pounds.

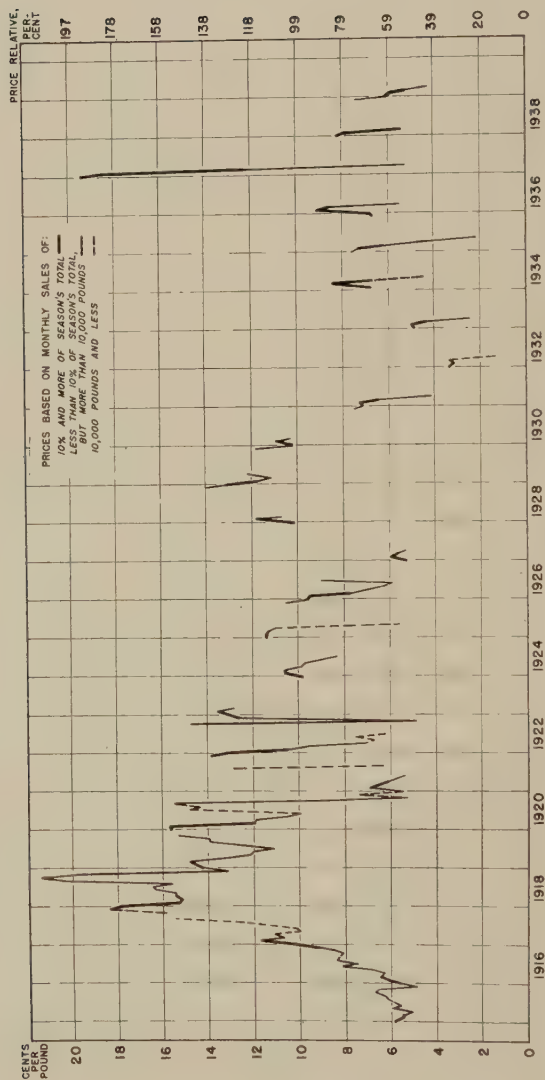


Figure 14. Tobacco, type 35 (One Sucker). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1914-1938. (For price relatives, average crop-year prices, 1920-1929 = 100.)

Tobacco is not marketed continuously but only during a relatively short marketing season. Monthly prices usually either decline thruout the season or rise for a time and then decline. A decided shortening of the season is noticeable. In any one season, prices seldom differed more than two cents during the months of heaviest marketings.

Table 27. Tobacco, type 35 (One Sucker). Prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (cents per pound).

Beginning Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
9												6.30
0												7.20
1												7.00
2												6.50
3												7.10
4	5.87	5.45	5.43	5.02	6.01	5.54	5.99	6.20*	6.29	6.81	6.55	5.60
5	4.99	5.71	6.16	6.49	6.30	6.81	8.21	7.47*	8.35	8.29*	8.04*	6.05
6	9.20	10.31	11.70	10.76	11.08	9.98*	10.12*	11.75*	12.50*	15.46*	.....	15.90*
7	18.25	17.83	15.24	15.19	15.44	15.49	16.36	16.46	15.58	20.31	21.45	19.47
8	13.11	14.30	14.59	14.83	13.16	12.15	12.02	11.11	12.68	13.99	14.00	15.32
9	.....	15.66	15.64	11.95	11.88	10.62	10.02	14.91*	14.31	15.46*	8.82	5.22
0	7.38*	5.50*	6.86	6.55	6.04	5.72	5.34	.....	12.79*	6.31*	.....	14.69
1	13.94	13.20	10.54	9.62	7.05	6.65*	7.57*	6.07*	.....	.....	.....	6.34
2	12.60	13.10	13.54	12.87	.....	.....	.....	.....	.....	14.75*	4.81	12.15
3	.....	9.82	10.61	10.61	9.77	9.72	9.09	8.26	.....	8.83*	.....	13.01
4	.....	11.41	11.41	11.31	10.92	5.57*	.....	.....	.....	14.24	.....	10.22
5	10.56	9.63	9.54	7.73	6.98	6.15	5.99*	8.97	.....	.....	4.00*	11.40
6	.....	5.30	5.93	5.67	5.27	.....	.....	.....	.....	.....	.....	8.75
7	10.15	10.11	11.86	10.74	.....	.....	.....	5.91*	.....	.....	.....	5.66
8	14.05	13.12	11.77	11.13	12.16	.....	.....	.....	.....	.....	.....	10.96
9	11.87	9.96	10.89	10.29	.....	.....	.....	.....	.....	.....	.....	12.44
0	7.46	7.09	7.16	6.32	4.11	.....	.....	.....	.....	.....	.....	10.46
1	.....	3.30	3.17	3.29	1.35*	.....	.....	.....	.....	.....	.....	6.98
2	.....	4.86	4.95	4.39	2.38	.....	.....	.....	.....	.....	.....	3.23
3	.....	.....	6.70	8.37	6.76	4.44*	.....	.....	.....	.....	.....	4.85
4	.....	7.60	7.28	6.12	4.73	2.18	.....	.....	.....	.....	.....	7.12
5	6.71	6.80	9.12	8.60	5.44	.....	.....	.....	.....	.....	.....	6.73
6	.....	19.37	18.40	12.22	5.31	.....	.....	.....	.....	.....	.....	8.04
7	.....	8.19	7.78	5.32	.....	.....	.....	.....	.....	.....	.....	16.65
8	7.41	6.07	5.84	5.24	4.28	.....	.....	.....	.....	.....	.....	7.41
												5.72

Annual prices for 1909-1914 are for the entire production of this type and are taken from Circular 249, "Tobacco Types, Uses and Markets," U. S. Department of Agriculture. No data for monthly prices for 1909-1913 are available. The crop-year average price for 1914 is distributed seasonally on the basis of a sample of monthly prices reported to the Kentucky Commissioner of Agriculture. Monthly prices for 1915-1938 are calculated from warehouse reports to the Commissioner of Agriculture.

* Based upon sales of less than 10,000 pounds.

Table 28. Tobacco, type 35 (One Sucker). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (average crop year prices, 1920-1929 = 100).

Beginning Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
9												62
0												71
1												69
2												64
3												70
4	58	54	54	50	59	55	59	61*	62	67	65	55
5	49	56	61	64	62	67	81	74*	82	79*	84	60
6	91	102	115	106	109	98*	100*	116*	123*	152*	.....	157*
7	180	176	150	150	152	153	161	162	154	200	212	192
8	129	141	144	146	130	120	119	110	125	138	138	151
9	.....	154	154	118	117	105	99	147*	141	152*	87	51
0	73*	54*	68	65	60	56	53	.....	126*	62*	.....	145
1	137	130	104	95	70	66*	75*	60*	.....	145*	47	63
2	124	129	134	127	.....	.....	.....	.....	.....	87*	.....	120
3	.....	97	105	105	96	96	90	81	.....	.....	.....	128
4	.....	113	113	112	108	55*	.....	.....	.....	140	.....	101
5	104	95	94	76	69	61	59*	88	.....	.....	39*	112
6	.....	52	58	56	52	.....	.....	.....	.....	.....	.....	86
7	100	100	117	106	.....	.....	.....	.....	58*	.....	.....	56
8	139	129	116	110	120	.....	.....	.....	.....	.....	.....	108
9	117	98	107	101	.....	.....	.....	.....	.....	.....	.....	123
0	74	70	71	62	41	.....	.....	.....	.....	.....	.....	103
1	.....	33	31	32	13*	.....	.....	.....	.....	.....	.....	69
2	.....	48	49	43	23	.....	.....	.....	.....	.....	.....	32
3	.....	.....	66	83	67	44*	.....	.....	.....	.....	.....	48
4	.....	75	72	60	47	21	.....	.....	.....	.....	.....	70
5	66	67	90	85	54	.....	.....	.....	.....	.....	.....	66
6	.....	191	181	121	52	.....	.....	.....	.....	.....	.....	79
7	.....	81	77	52	.....	.....	.....	.....	.....	.....	.....	164
8	73	60	58	52	42	.....	.....	.....	.....	.....	.....	73
												56

* Based upon sales of less than 10,000 pounds.

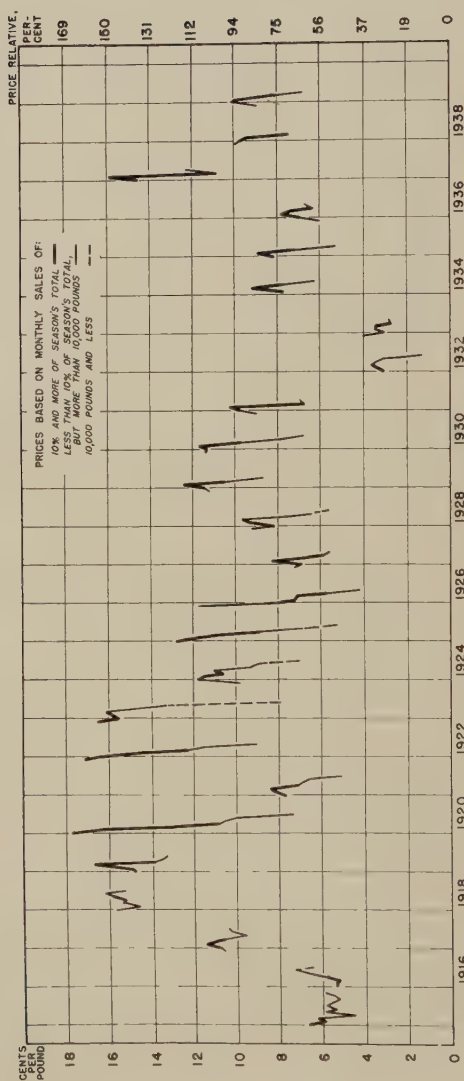


Figure 15. Tobacco, type 36 (Green River). Prices paid for growers' sales in Kentucky warehouses, and relatives of prices, by months, crop years 1914-1938. (For price relatives, average crop year prices, 1920-1929 = 100.)

Tobacco is not marketed continuously but only during a relatively short marketing season. Monthly prices usually either decline thruout the season or rise for a time and then decline. A decided shortening of the season is noticeable.

Table 29. Tobacco, type 36 (Green River). Prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (cents per pound).

Year beginning Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
1909													6.50
1910													7.00
1911													7.25
1912													6.25
1913													6.75
1914		6.76	5.98	6.26	4.54	5.98	5.44	5.94	5.66	5.26	5.48	5.97	6.06
1915		5.43	5.36	6.30	5.80	6.74	7.36	6.52*				8.88	5.52
1916	10.61	10.84	11.46	11.10	10.62	9.64	10.28	10.37					11.11
1917		15.73	14.66	15.38	15.30	15.92	16.21	15.30					15.52
1918		14.87	15.04	16.77	13.86	13.55	13.34						14.94
1919		17.74	16.23	12.96	10.82	10.62	9.99	7.40					14.88
1920		7.68	8.18	8.46	7.09	6.89	6.62	5.09					7.84
1921	17.20	16.56	14.47	12.37	11.54	9.06							15.01
1922	16.52	15.61	15.93	16.14	14.58	13.31	7.95*						15.79
1923	9.87	11.81	11.59	10.55	11.09	9.26	8.83	7.05*					11.18
1924		12.87	12.04	10.77	8.99	6.93	5.25*						11.39
1925	11.73	8.34	7.27	7.09	5.70	4.19							7.13
1926	7.28	6.97	8.31	7.13	5.89	5.60							7.27
1927	9.16	8.15	9.42	9.69	7.62	6.33	5.66*						9.07
1928	11.23	11.43	12.45	10.48	8.71								11.42
1929	11.36	11.34	11.68	9.75	7.84	6.84							10.72
1930	8.97	9.82	10.28	6.75	6.93								8.94
1931		2.98	3.31	3.57	3.40	3.04	1.27						3.31
1932	3.96	3.08	3.41	3.47	2.71	2.82							3.33
1933			7.73	9.23	7.79	6.31							7.88
1934		8.09	8.95	7.26	5.29								8.13
1935	6.09	6.96	7.83	7.45	6.38	6.73							7.32
1936		14.55	15.94	10.86	12.25								14.82
1937	9.95	9.78	9.42	7.42									9.11
1938	8.97	10.21	9.84	8.09	6.83								9.62

Annual prices for 1909-1913 were furnished by buyers of Green River tobacco but data are not available from which monthly prices can be estimated. Monthly prices for 1914-1938 are calculated from warehouse reports to the Kentucky Commissioner of Agriculture.

* Based upon sales of less than 10,000 pounds.

Table 30. Tobacco, type 36 (Green River). Relatives of prices paid for growers' sales in Kentucky warehouses, by months, 1914-1938 (average crop year prices, 1920-1929 = 100).

Year beginning Nov. 1	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Crop-year wtd. average
1909													61
1910													66
1911													63
1912													59
1913													63
1914		63	56	59	43	56	51	56	53	49	51	56	57
1915		51	50	50	54	63	69	61*				83	52
1916	99	101	107	104	99	90	96	97					104
1917		147	137	144	143	149	152	143					145
1918		139	141	157	130	127	125						140
1919		166	152	121	101	99	94	69					139
1920		72	77	79	66	65	62	48					73
1921	161	155	135	116	108	85							141
1922	155	146	149	151	137	125	74*						148
1923	92	111	109	99	104	87	83	66*					105
1924		121	113	101	84	65	49*						107
1925	110	78	68	66	53	39							67
1926	68	65	78	67	55	52							68
1927	86	76	88	91	71	59	53*						85
1928	105	107	117	98	82								107
1929	106	106	109	91	73	64							100
1930	84	92	96	63	65								84
1931		28	31	33	32	28	12						31
1932	37	29	32	32	25	26							31
1933			72	86	73	59							74
1934		76	84	68	50								76
1935	57	65	73	70	60	63							69
1936		136	149	102	114								139
1937	93	92	88	69									85
1938	84	96	92	76	64								90

* Based upon sales of less than 10,000 pounds.

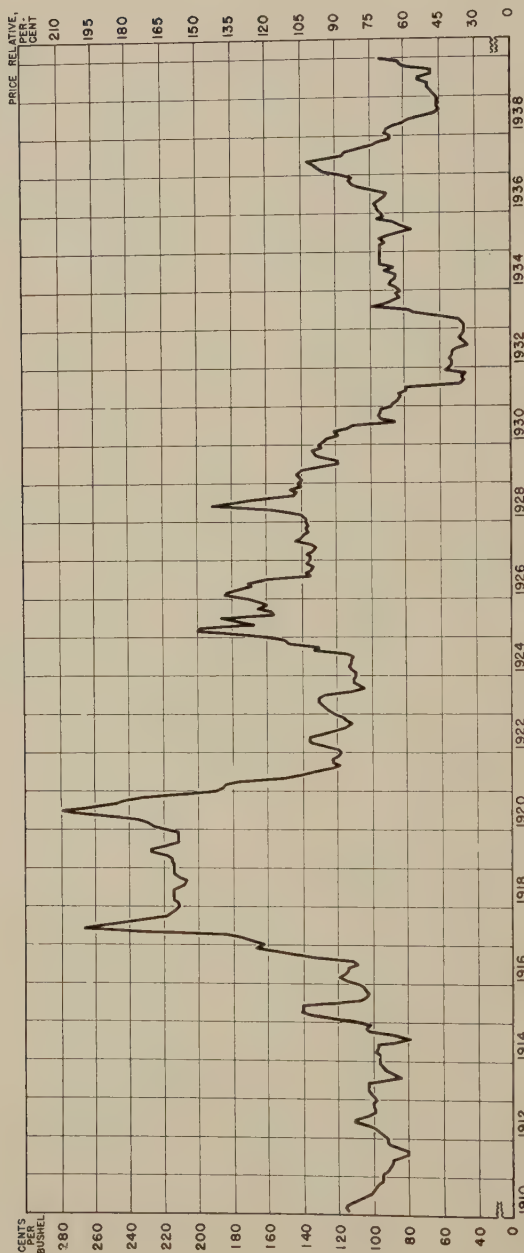


Figure 16. Wheat. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

During the four years, 1917-1920, wheat prices were at the abnormally high level of \$2.05 to \$2.80 a bushel. High prices prevailed also in 1925, the first half of 1926, and in 1928. During the depression, prices dropped to less than 50 cents a bushel.

Table 31. Wheat. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per bushel)¹.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	115	116	116	112	108	104	101	100	98	97	94	94	101
1911	94	92	90	89	89	86	80	80	85	90	92	92	82
1912	94	96	98	103	110	110	102	98	99	100	100	99	101
1913	100	101	102	102	102	93	84	88	93	94	96	96	88
1914	96	96	98	97	97	88	78	88	102	104	102	106	86
1915	120	136	141	140	139	122	106	104	102	104	105	108	108
1916	116	120	116	114	114	109	112	132	144	156	167	162	124
1917	166	174	184	229	266	256	239	228	218	216	213	211	230
1918	211	214	214	214	214	212	208	206	212	214	214	214	209
1919	214	215	216	218	227	228	218	212	211	212	212	217	216
1920	226	229	234	250	272	279	264	248	242	232	206	190	253
1921	185	184	176	152	140	133	122	118	122	123	118	117	125
1922	119	126	134	136	136	128	118	114	111	114	116	121	118
1923	125	126	129	131	130	126	112	104	106	110	110	109	111
1924	109	112	113	112	112	110	115	123	130	148	149	157	123
1925	180	200	198	168	178	186	156	157	165	159	165	170	161
1926	185	182	174	169	170	160	134	137	134	133	137	135	139
1927	134	137	133	132	134	143	140	138	136	137	136	137	138
1928	137	140	146	158	190	174	165	144	142	146	139	141	156
1929	139	141	142	139	128	119	118	129	132	133	128	129	124
1930	126	125	119	121	113	111	87	94	96	94	93	88	93
1931	87	84	82	84	80	80	49	47	48	47	57	54	52
1932	53	53	55	53	53	51	44	47	49	48	46	46	46
1933	47	48	49	60	76	78	98	90	86	83	85	82	90
1934	85	89	88	85	85	92	87	94	95	94	94	94	90
1935	95	94	90	94	91	83	76	82	86	96	92	93	81
1936	96	96	97	94	92	91	98	106	110	112	111	117	102
1937	126	129	132	136	128	116	114	105	99	96	88	88	110
1938	92	91	86	81	78	71	63	60	61	61	61	61	64
1939	64	65	66	67	72	72	65	65	80	82	84	94	68

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets" Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of crop years, 1925-1929.

Table 32. Wheat. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	86	87	87	84	81	78	76	75	74	73	71	71	76
1911	71	69	68	67	67	65	60	60	64	68	69	69	62
1912	71	72	74	77	83	83	77	74	74	75	75	74	76
1913	75	76	77	77	77	70	63	66	70	71	72	72	66
1914	72	72	74	73	73	66	59	66	77	78	77	80	65
1915	90	102	106	105	105	92	80	78	77	78	79	81	81
1916	87	90	87	86	86	82	84	99	108	117	126	122	93
1917	125	131	138	172	200	192	180	171	164	162	160	159	173
1918	159	161	161	161	161	159	156	155	159	161	161	161	157
1919	161	162	162	164	171	171	164	159	159	159	159	163	162
1920	170	172	176	188	205	210	198	186	182	174	155	143	190
1921	139	138	132	114	105	100	92	89	92	92	89	88	94
1922	89	95	101	102	102	96	89	86	83	86	87	91	89
1923	94	95	97	98	98	95	84	78	80	83	83	82	83
1924	82	84	85	84	84	83	86	100	98	111	112	118	92
1925	135	150	149	126	134	140	117	118	124	120	124	128	121
1926	139	137	131	127	128	120	101	103	101	100	103	102	105
1927	101	103	100	99	101	108	105	104	102	103	102	103	104
1928	103	105	110	119	143	131	124	108	107	110	105	106	117
1929	105	106	107	105	96	89	89	97	99	100	96	97	93
1930	95	94	89	91	85	83	65	71	72	71	70	66	70
1931	65	63	62	63	60	60	37	35	36	35	43	41	39
1932	40	40	41	40	40	38	33	35	37	36	35	35	35
1933	35	36	37	45	57	59	74	68	65	62	64	62	68
1934	64	67	66	64	64	69	65	71	71	71	71	71	68
1935	71	71	68	71	68	62	57	62	65	72	69	70	61
1936	72	72	73	71	69	68	74	80	83	84	83	88	77
1937	95	97	99	102	96	87	86	79	74	72	66	66	83
1938	69	68	65	61	59	53	47	45	46	46	46	46	48
1939	48	49	50	50	54	54	49	49	60	62	63	71	51

MINOR CROPS

Table 33. Alfalfa hay. Prices received by Kentucky producers on the 15th of the month 1915-1939 (dollars per ton).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1915	19.10	19.90	19.50	18.40	18.60	18.30	15.30	14.60	13.60	14.00	13.00	13.50	15.30
1916	14.50	14.30	13.80	14.10	14.50	14.20	12.90	12.60	13.00	12.70	12.45	13.70	13.10
1917	14.40	16.30	17.70	19.00	19.60	18.40	17.20	18.50	19.00	21.60	23.90	26.20	20.10
1918	29.60	32.20	31.70	28.60	26.50	21.80	20.30	23.70	24.00	27.00	26.90	25.50	26.60
1919	27.50	27.00	26.70	28.20	30.00	31.50	25.50	27.50	30.00	27.20	28.10	27.50	27.50
1920	31.70	32.70	33.75	36.60	36.50	35.30	29.20	26.30	27.00	25.00	25.00	26.00	28.80
1921	24.00	22.00	20.00	20.00	18.00	16.50	17.00	16.10	16.00	16.00	15.50	17.30	18.10
1922	17.50	17.40	19.00	19.00	18.00	16.50	15.20	14.20	14.50	15.80	15.30	16.40	16.10
1923	15.80	17.00	16.80	17.50	17.10	17.40	16.00	16.60	17.50	18.00	18.50	19.00	17.30
1924	19.50	20.00	22.00	22.50	22.70	22.20	22.00	21.20	20.60	20.60	21.00	21.70	21.10
1925	20.50	20.60	18.80	18.80	21.40	17.00	17.30	17.90	18.60	20.40	21.60	18.40	19.10
1926	20.60	23.00	22.10	20.80	21.60	20.30	21.70	20.20	20.20	19.20	20.50	20.00	20.30
1927	20.00	20.50	20.50	20.00	18.30	19.50	18.00	17.00	17.50	16.50	16.70	17.00	18.10
1928	17.20	18.00	18.70	20.00	20.50	19.70	18.00	18.00	18.80	18.80	19.70	20.40	18.10
1929	21.50	22.50	23.50	22.40	22.40	21.50	20.00	19.00	18.00	18.60	19.40	19.90	20.30
1930	19.50	19.50	19.60	19.30	18.40	18.00	19.00	22.30	23.90	24.40	24.40	24.40	22.30
1931	24.40	22.60	23.30	23.30	22.50	17.20	15.10	14.50	14.00	12.80	12.60	12.80	16.10
1932	11.00	11.50	12.40	11.30	13.00	9.50	9.50	9.80	9.70	9.20	9.20	9.80	10.10
1933	9.20	9.50	9.00	9.40	9.10	9.50	9.80	10.40	10.60	10.40	10.10	9.90	9.90
1934	10.50	10.90	11.90	11.60	12.20	11.60	12.00	13.50	13.50	16.50	16.00	16.50	13.10
1935	17.00	15.60	15.00	15.20	14.50	12.10	11.80	11.50	10.70	10.30	10.50	11.10	12.10
1936	10.90	12.10	12.50	12.60	12.30	12.00	15.80	19.30	20.30	20.40	20.20	21.00	17.10
1937	22.00	22.90	23.50	23.70	22.00	18.80	15.00	13.80	12.90	12.90	12.50	13.00	16.10
1938	14.00	15.00	15.00	13.80	14.00	11.90	11.40	11.60	11.30	10.70	9.70	10.50	11.10
1939	10.70	10.70	10.80	10.50	10.30	10.00	9.70	10.10	10.40	10.30	11.00	11.20	10.10

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets" Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of all hay, crop year 1925-1929.

Table 34. Buckwheat. Prices received by Kentucky producers on the 15th of the month 1933-1939 (cents per bushel).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1933	50	50	50	52	55	65	80	80	80	80	75	70	75
1934	75	75	75	80	85	90	85	85	83	90	85	80	82
1935	80	82	82	82	82	80	80	85	85	85	83	85	83
1936	90	90	90	90	85	85	92	95	95	95	92	92	92
1937	90	88	88	95	95	92	95	95	85	85	80	75	88
1938	75	76	80	75	80	75	75	75	75	73	70	73	75
1939	75	75	75	70	72	72	60	58	65	64	64	66	66

¹ Monthly prices from "Crops and Markets" Bureau of Agricultural Economics, U. S. Department of Agriculture.

Table 35. Mixed clover and timothy hay. Prices received by Kentucky producers on the 15th of the month, 1915-1939 (dollars per ton).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1915	16.70	17.40	17.20	17.10	17.30	16.30	14.00	12.80	11.60	12.10	11.70	12.20	13.92
1916	12.30	12.40	12.80	13.20	13.50	13.50	12.00	11.80	11.63	11.75	11.90	12.70	12.27
1917	13.10	14.10	15.00	16.40	17.50	17.50	15.00	15.70	16.90	18.40	20.70	22.10	17.37
1918	25.10	27.80	28.50	27.50	25.30	21.50	19.60	20.40	22.00	24.30	23.80	24.00	23.94
1919	24.50	24.50	25.00	27.30	28.80	28.90	25.30	24.40	25.40	24.60	25.34	25.90	25.34
1920	28.10	30.10	32.00	32.90	35.30	35.00	29.10	25.60	25.00	23.00	24.00	22.00	26.57
1921	22.00	20.00	18.50	17.30	17.80	16.00	15.00	15.20	15.00	15.00	14.50	15.60	16.59
1922	15.20	16.00	16.70	17.60	16.50	15.60	14.80	13.40	13.50	14.30	13.60	15.30	14.86
1923	16.00	16.60	16.50	16.00	16.70	17.20	16.40	16.30	17.30	17.80	16.50	17.50	16.79
1924	19.00	19.50	20.50	21.00	20.60	21.00	20.00	16.50	17.00	17.00	16.70	18.30	18.31
1925	19.00	19.50	18.10	15.50	16.60	17.10	16.30	16.50	18.20	19.10	19.40	18.20	18.09
1926	19.50	19.60	19.60	20.20	20.70	20.00	18.90	18.20	18.00	17.80	18.30	18.00	18.70
1927	18.50	19.00	18.00	18.00	17.50	19.00	17.00	16.50	15.50	15.00	15.20	15.00	16.56
1928	15.70	15.50	16.30	16.90	16.90	17.30	16.30	16.20	15.80	16.10	16.80	16.90	16.33
1929	17.60	19.00	19.40	19.10	18.30	17.50	16.50	15.40	15.80	15.80	16.10	16.40	16.86
1930	16.10	16.20	16.20	16.30	15.90	16.60	16.50	20.40	21.10	21.30	20.50	20.20	18.84
1931	20.50	20.60	20.80	20.50	19.50	17.30	15.30	14.50	13.80	12.10	12.60	10.90	15.40
1932	10.80	10.90	10.80	10.80	9.40	8.50	8.50	9.00	9.00	8.10	8.20	8.80	9.28
1933	8.50	8.50	8.00	8.20	8.30	8.30	9.30	9.30	9.30	8.60	8.90	8.70	8.75
1934	9.00	10.00	10.10	10.10	10.70	9.80	10.80	12.00	13.00	12.50	14.00	13.80	11.84
1935	14.00	13.50	12.30	12.00	12.00	11.40	10.40	9.50	9.30	8.80	8.80	9.70	10.60
1936	9.40	10.30	10.20	10.30	10.40	10.50	13.20	16.50	17.10	18.00	17.40	18.00	14.64
1937	19.00	20.00	21.00	21.50	20.20	16.70	14.50	12.50	11.60	11.20	11.10	11.40	14.59
1938	11.80	12.80	12.50	11.40	11.20	10.10	9.60	9.40	9.40	9.30	9.20	9.50	10.27
1939	9.40	10.00	9.40	9.70	9.80	8.90	9.00	9.60	10.00	10.00	9.70	11.00	9.87

¹ Prices January 1915 thru November 1934 are for clover hay. Mixed clover and timothy prices thus commence with December, 1934. Prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of all hay, crop years, 1925-1929.

Table 36. Prairie hay. Prices received by Kentucky producers on the 15th of the month, 1917-1939 (dollars per ton).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1917	12.00		14.00	14.50	13.50	13.00		13.00	11.50	10.50	15.00	12.00	12.71
1918	12.00	14.00	13.00	12.00	11.00	12.00	12.80	12.60	13.10	14.50	13.50	12.60	12.96
1919	13.50	14.40	14.30	15.40	15.50	14.50	14.90	14.00	13.00	12.50	11.50	10.70	13.10
1920	10.70	11.00	12.00	12.00	13.00	14.00	14.10	14.20	14.90	14.00	13.70	13.90	13.23
1921	14.50	15.20	14.50	13.50	12.50	13.50	12.00	12.60	12.60	11.30	10.00	9.00	12.11
1922	9.00	9.00	8.60	7.60	6.70	6.70	6.00	5.00	5.50	5.70	5.80	6.50	6.68
1923	6.00	7.00	7.40	6.50	6.50	6.60	7.00	8.00	8.00	8.20	7.50	7.00	7.27
1924	7.00	8.00	8.00	8.00	7.00	7.00	7.00	8.00	9.70	10.00	12.00	11.70	9.22
1925	11.00	11.00	10.00	10.00	10.00	10.00	10.00	9.00	6.00	5.60	5.00	6.00	8.02
1926	6.00	9.00	8.60	8.30	8.20	8.00	9.50	10.00	10.00	10.00	9.00	10.00	9.11
1927	11.00	10.00	11.00	10.00	10.00	10.00	9.00	8.50	8.00	7.00	7.00	8.00	8.75
1928	7.00	8.00	8.00	8.00	8.00	8.00	7.00	7.00	6.00	5.00	5.00	6.00	6.56
1929	6.00	5.00	6.00	6.00	5.00	4.50	5.00	5.00	4.50	5.40	5.50	5.50	5.33

¹ Monthly prices from "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of all hay, crop years, 1925-1929.

Table 37. Red clover seed. Prices received by Kentucky producers on the 15th of the month, 1932-1939 (dollars per bushel).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1932	7.70		8.20	8.70	9.30	8.50	8.50	7.30	6.50	5.50	4.95	5.40	7.32
1933	5.70	5.30	5.50	4.75	5.00	5.50	6.00	6.00	7.00	6.50	6.00	5.90	5.76
1934	5.90	6.50	6.60	7.50	6.60	7.50	7.30	8.70	9.00	11.00	9.00	10.00	7.97
1935	10.00	13.00	12.00	11.50	10.90	11.50	9.00	10.00	9.00	9.50	9.30	9.50	10.43
1936	11.00	10.00	10.00	11.20	11.40	11.30	12.00	12.00	12.00	13.00	14.00	15.00	11.91
1937	15.60	16.50	22.50	21.50	21.00	20.00	19.00	19.00	17.30	18.00	17.00	16.00	18.62
1938	17.00	20.00	20.00	21.00	21.80	18.00	17.00	12.00	9.60	7.60	7.50	8.10	14.97
1939	9.00	9.30	9.90	10.00	11.00	12.00	10.50	11.00	9.10	10.40	9.90	10.00	10.18

¹ Monthly prices from "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

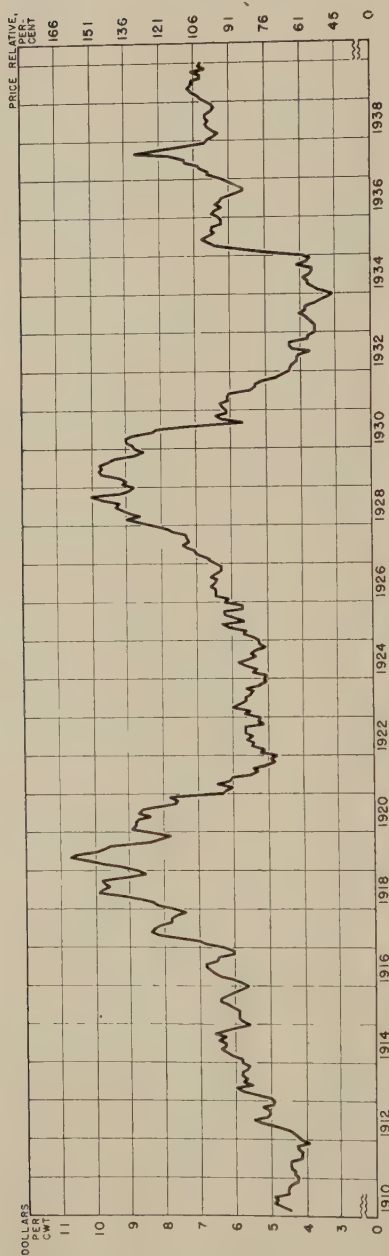


Figure 17. Beef cattle. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices rose during the base period, 1921-29, to levels almost as high as those in 1918 and 1919. In 1933 and 1934 prices were lower than in prewar years but made a sharp recovery after 1934.

MAJOR LIVESTOCK AND LIVESTOCK PRODUCTS

Table 38. Beef cattle. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per 100 pounds).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	4.40	4.40	4.70	4.90	4.80	4.90	4.50	4.50	4.50	4.40	4.20	4.20	4.49
1911	4.30	4.30	4.40	4.40	4.40	4.10	4.10	4.10	4.20	4.20	3.90	4.10	4.17
1912	4.20	4.30	4.50	4.80	5.20	5.50	5.10	5.00	5.00	5.20	4.90	4.90	4.97
1913	5.00	5.50	5.80	6.00	5.50	5.80	5.70	5.80	5.80	5.70	5.60	5.80	5.69
1914	5.80	6.10	6.20	6.40	6.30	6.30	6.50	6.30	6.60	6.30	6.00	5.60	6.24
1915	5.80	5.90	5.90	5.90	6.00	6.20	6.40	6.40	6.30	6.10	5.80	5.60	6.08
1916	5.80	6.00	6.40	6.60	6.70	6.80	6.80	6.50	6.40	6.00	6.00	6.30	6.33
1917	6.80	7.10	7.70	8.20	8.40	8.30	8.10	7.80	7.80	7.70	7.40	7.70	7.76
1918	8.10	8.30	8.60	9.20	9.90	9.80	9.60	9.70	9.80	9.00	8.50	8.80	9.18
1919	9.20	9.80	10.20	10.70	10.60	9.90	9.70	9.40	8.40	8.10	7.80	8.30	9.01
1920	8.90	8.80	8.80	8.75	8.40	8.70	8.60	8.20	7.70	7.60	7.80	6.30	8.06
1921	6.20	6.00	6.50	6.10	6.00	5.50	5.30	5.40	5.00	4.80	4.90	4.70	5.32
1922	5.20	5.10	5.50	5.40	5.60	5.40	5.60	5.60	5.60	5.10	5.30	5.20	5.38
1923	5.70	5.50	6.00	5.80	5.60	5.60	5.50	5.40	5.60	5.20	5.00	5.10	5.42
1924	5.00	5.40	5.30	5.60	5.80	5.50	5.30	5.50	5.30	5.00	5.20	5.20	5.29
1925	5.40	5.70	5.60	6.10	6.30	5.60	5.90	6.20	6.20	5.70	5.70	6.20	5.90
1926	6.10	6.50	6.50	6.50	6.60	6.50	6.40	6.60	6.40	6.30	6.30	6.40	6.41
1927	6.60	6.70	7.00	7.10	7.30	7.40	7.20	7.30	7.30	7.70	7.80	8.10	7.39
1928	8.50	9.00	8.60	8.90	9.10	9.30	9.20	9.70	10.00	9.20	8.90	8.80	9.21
1929	9.10	9.00	9.20	9.70	9.80	9.70	9.80	9.50	9.30	8.70	8.50	8.70	9.18
1930	8.80	9.00	9.00	8.80	8.20	8.10	7.10	5.60	6.30	6.40	6.10	6.10	6.98
1931	6.20	6.30	6.10	6.10	6.00	5.40	5.36	5.30	5.10	4.60	4.50	4.30	5.20
1932	4.30	4.20	4.10	4.10	4.00	3.70	4.20	4.30	4.30	3.75	3.75	3.55	4.00
1933	3.55	3.60	3.65	3.75	3.85	4.00	3.85	3.85	3.60	3.35	3.15	3.05	3.57
1934	3.35	3.65	3.80	3.75	3.90	3.70	3.65	3.65	4.10	3.75	3.70	3.90	3.76
1935	4.95	5.60	6.40	6.60	6.80	6.60	6.40	6.50	6.50	6.20	6.20	6.30	6.30
1936	6.50	6.40	6.20	6.40	6.30	6.20	5.80	5.60	5.60	5.80	6.00	6.20	5.96
1937	6.60	6.60	6.80	6.90	7.30	7.30	7.70	8.70	7.90	7.30	6.70	6.60	7.35
1938	6.40	6.30	6.50	6.60	6.70	6.60	6.70	6.70	6.50	6.40	6.50	6.60	6.54
1939	6.80	6.90	7.10	7.20	7.10	7.10	6.80	6.80	7.10	6.70	6.90	6.80	6.91

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 39. Beef cattle. Relatives of prices received by Kentucky producers on the 15th of month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	67	67	71	74	73	74	68	68	68	67	64	64	68
1911	65	65	67	67	67	62	62	62	64	64	59	62	63
1912	64	65	68	73	79	83	77	76	76	79	74	74	75
1913	76	83	88	91	83	88	86	88	88	86	85	88	86
1914	88	92	94	97	95	95	98	95	100	95	91	85	94
1915	88	89	89	89	91	94	97	97	95	92	88	85	92
1916	88	91	97	100	101	103	103	98	97	91	91	95	96
1917	103	107	116	124	127	126	123	118	118	116	112	116	117
1918	123	126	130	139	150	148	145	147	148	136	129	133	139
1919	139	148	154	162	160	150	147	142	127	123	118	126	136
1920	135	133	133	132	127	132	130	124	116	115	118	95	122
1921	94	91	98	92	91	83	80	82	76	73	74	71	80
1922	79	77	83	82	85	82	85	85	85	77	80	79	81
1923	86	83	91	88	85	85	83	82	85	79	76	77	82
1924	76	82	80	85	88	83	80	83	80	76	79	79	80
1925	82	86	85	92	95	85	89	94	94	86	86	94	89
1926	92	98	98	98	100	98	97	100	97	95	95	97	97
1927	100	101	106	107	110	112	109	110	110	116	118	123	112
1928	129	136	130	135	138	141	139	147	151	139	135	133	139
1929	138	136	139	147	148	147	148	144	141	132	129	132	139
1930	133	136	136	133	124	123	107	85	95	97	92	92	106
1931	94	95	92	92	91	82	80	80	77	70	68	65	79
1932	65	64	62	62	61	56	64	65	65	57	57	54	61
1933	54	54	55	57	58	61	58	58	54	51	48	46	54
1934	51	55	57	57	59	56	55	55	62	57	56	59	57
1935	75	85	97	100	103	100	97	98	98	94	94	95	95
1936	98	97	94	97	95	94	88	85	85	88	91	94	90
1937	100	100	103	104	110	110	116	132	120	110	101	100	111
1938	97	95	98	100	101	100	101	101	98	97	98	100	99
1939	103	104	107	109	107	107	103	103	107	101	104	103	105

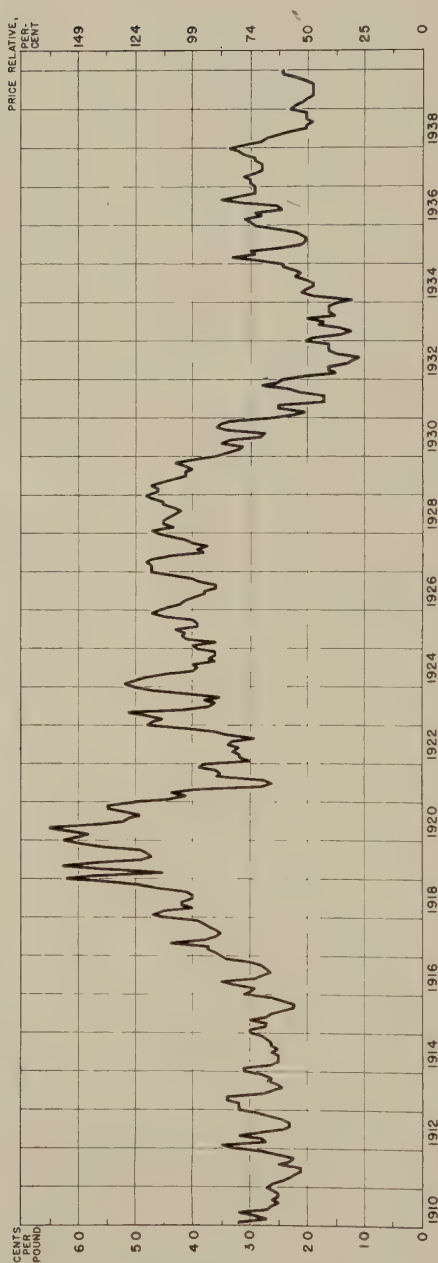


Figure 18. Butterfat. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100 percent.)

Prices usually have been seasonally high in winter and low in summer. Butterfat prices during the war were only 50 percent higher than the 1921-29 level of prices that prevailed in this state, while during the depression prices dropped below prewar levels and to almost one-quarter of the 1921-29 level.

Table 40. Butterfat. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per pound).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	32	27	29	32	27	26	25	26	25	25	26	27	27
1911	26	24	23	22	21	21	25	23	22	25	28	33	24
1912	35	27	28	32	28	24	23	23	24	26	29	32	27
1913	32	32	34	34	28	26	24	25	27	26	28	31	28
1914	31	26	25	25	25	26	25	26	26	27	28	30	27
1915	30	27	27	30	27	26	24	22	22	24	26	31	26
1916	30	29	33	35	29	28	26	27	28	30	34	35	30
1917	36	37	37	44	38	36	35	36	37	38	39	45	38
1918	47	45	40	42	42	40	40	41	46	49	55	62	45
1919	57	45	56	63	57	49	47	48	49	56	60	63	54
1920	60	58	62	65	57	52	51	49	52	55	55	50	55
1921	44	41	44	40	28	26	28	36	35	36	39	38	35
1922	30	32	32	33	32	34	33	29	34	36	41	48	34
1923	47	45	48	51	41	37	36	38	35	42	47	50	42
1924	52	50	48	45	40	39	40	36	37	36	36	39	41
1925	40	36	41	42	41	43	39	39	40	45	47	46	42
1926	44	42	41	40	38	38	36	36	39	40	44	47	40
1927	47	47	48	47	44	38	39	37	40	41	44	46	42
1928	47	43	45	45	44	43	42	43	45	45	47	48	45
1929	46	46	47	45	43	41	41	40	41	43	40	36	42
1930	34	32	31	35	33	28	27	34	36	35	33	26	32
1931	22	20	25	25	17	17	17	21	23	28	25	24	22
1932	20	15	16	16	13	12	11	15	16	16	16	20	15
1933	19	14	12	14	18	17	20	15	16	16	16	15	16
1934	12	19	21	20	19	19	20	22	21	22	24	24	20
1935	28	33	29	30	24	21	20	20	21	22	26	29	24
1936	30	31	28	29	24	25	31	35	32	29	29	29	29
1937	30	30	31	29	28	28	28	29	29	31	32	34	30
1938	31	28	27	25	23	20	20	19	20	20	20	23	22
1939	22	21	20	19	19	19	19	19	20	22	24	24	20

¹ Prices from January, 1910, to August, 1920, are estimated from monthly quotations of Chicago creamery extras on the basis of the average relationship between Chicago creamery extras and Kentucky butterfat prices in corresponding months, 1921-1925. Prices of Chicago creamery extras are from Statistical Bulletin No. 25; monthly butterfat prices, September, 1920, and later are from Statistical Bulletin No. 16 and "Crops and Markets," publications of the Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1930-1932.

Table 41. Butterfat. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	79	67	72	79	67	65	62	65	62	62	65	67	67
1911	65	60	57	55	52	52	62	57	55	62	69	82	60
1912	87	67	69	79	69	60	57	57	60	65	72	79	67
1913	79	79	84	84	69	65	60	62	67	65	69	77	69
1914	77	65	62	62	62	65	62	65	65	67	69	74	67
1915	74	67	67	74	67	65	60	55	55	60	65	77	65
1916	74	72	82	87	72	69	65	67	69	74	84	87	73
1917	89	92	92	109	94	89	87	89	92	94	97	112	94
1918	117	112	99	104	104	99	99	102	114	122	136	154	112
1919	141	112	139	156	141	122	117	119	122	139	149	156	134
1920	149	144	154	161	141	129	127	122	129	136	136	124	136
1921	109	102	109	99	69	65	69	89	87	89	97	94	87
1922	74	79	79	82	79	84	82	72	84	89	102	119	84
1923	117	112	119	127	102	92	89	94	87	104	117	124	104
1924	129	124	119	112	99	97	99	89	92	89	89	97	102
1925	99	89	102	104	102	107	97	97	99	112	117	114	104
1926	109	104	102	99	94	94	89	89	97	99	109	117	99
1927	117	117	119	117	109	94	97	92	99	102	109	114	104
1928	117	107	112	112	109	107	104	107	112	112	117	119	112
1929	114	114	117	112	107	102	102	99	102	107	99	89	104
1930	84	79	77	87	82	69	67	84	89	87	82	65	79
1931	55	50	62	62	42	42	42	52	57	69	62	60	55
1932	50	37	40	40	32	30	27	37	40	40	40	50	37
1933	47	35	30	35	45	42	50	37	40	40	40	37	40
1934	30	47	52	50	47	47	50	55	52	55	60	60	50
1935	69	82	72	74	60	52	50	50	52	55	65	72	60
1936	74	77	69	72	60	62	77	87	79	72	72	72	72
1937	74	74	77	72	69	69	69	72	72	77	79	84	74
1938	77	69	67	62	57	50	50	47	50	50	50	57	55
1939	55	52	50	47	47	47	47	47	50	55	60	60	50

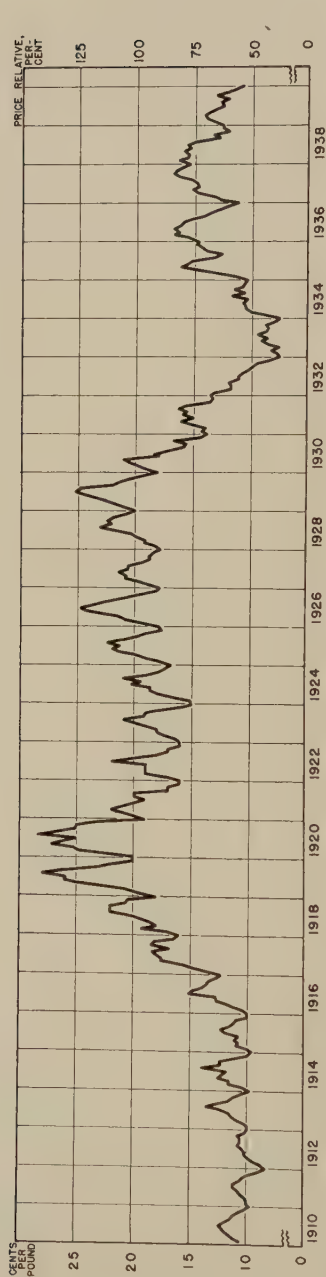


Figure 19. Chickens. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

From 1910 to 1929 there is clear evidence of a seasonal price movement, lowest prices occurring in December and January and highest in June and July. Since 1929, the seasonal pattern is less noticeable. During the thirty-year period, prices of chickens have moved within a narrower range than that of any other farm product. The highest point of prices in 1920 was 142 percent of the 1921-1929 average while the low point in 1933 was 39 percent, a range of 103 percent. From 1921 to 1929, chicken prices were maintained at a higher level, relative to World War prices, than those of most farm products.

Table 42. Chickens. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per pound).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	10.6	11.2	11.6	12.0	12.2	12.4	12.1	11.4	11.2	10.8	10.2	9.8	11.5
1911	9.9	10.0	10.2	10.6	10.8	11.2	11.2	10.6	10.3	10.0	9.0	8.4	10.3
1912	8.9	9.6	10.0	10.2	10.2	10.5	10.7	10.6	10.6	10.7	10.2	9.9	10.2
1913	10.0	10.4	11.0	11.4	11.7	12.3	13.5	12.7	11.7	11.3	10.6	9.8	11.4
1914	10.5	11.6	11.7	12.6	12.2	11.8	14.0	12.5	12.4	11.3	10.1	9.6	11.7
1915	10.0	11.0	10.9	11.2	10.8	11.9	12.4	11.5	11.3	11.0	10.1	9.9	11.1
1916	10.3	11.2	11.9	12.8	12.8	15.1	15.0	14.0	13.7	13.4	12.8	12.5	12.7
1917	13.5	14.9	15.6	17.6	17.6	18.1	18.3	16.9	18.4	18.2	16.3	16.0	16.8
1918	17.0	19.4	18.0	18.5	19.3	20.0	22.0	22.0	22.1	20.6	20.5	18.1	19.5
1919	19.5	20.3	22.5	25.0	26.0	26.0	28.0	26.0	23.0	22.0	20.0	20.0	23.6
1920	21.5	24.7	25.3	27.2	26.0	25.0	28.5	26.5	25.0	25.0	23.0	19.0	25.4
1921	20.0	21.0	22.0	21.0	20.0	19.0	20.0	20.0	17.0	17.0	16.0	16.0	19.9
1922	17.0	19.0	19.0	19.0	19.0	22.0	20.0	18.0	17.0	17.0	16.0	16.0	18.6
1923	16.3	17.4	18.0	18.0	19.0	20.0	21.0	19.3	19.0	18.0	16.1	15.0	18.3
1924	15.1	16.7	18.1	18.6	18.6	20.4	19.4	21.0	18.9	17.8	17.4	16.8	18.4
1925	17.8	18.7	19.8	21.3	21.9	21.2	22.4	21.0	19.8	19.0	17.6	17.8	20.2
1926	19.5	20.9	21.4	22.7	24.3	24.9	23.4	22.4	20.7	19.5	18.2	17.8	21.8
1927	18.7	19.7	20.8	20.9	21.4	20.6	20.6	19.4	18.7	18.7	18.4	17.8	20.1
1928	18.2	19.2	19.3	20.0	20.2	21.9	23.2	22.1	22.4	22.0	20.9	19.9	20.5
1929	20.7	21.6	22.3	23.6	24.4	25.2	24.8	22.0	21.4	20.9	19.4	18.1	22.5
1930	19.0	19.8	20.6	21.3	18.0	18.3	17.0	15.8	15.7	16.8	14.5	13.8	18.5
1931	14.5	14.1	15.4	16.2	15.0	16.0	15.6	16.5	15.5	13.5	13.4	13.6	15.2
1932	13.3	11.8	11.8	12.0	11.3	11.1	10.8	10.2	10.1	9.5	8.5	7.5	11.0
1933	7.8	8.5	7.6	8.6	9.1	8.6	9.7	8.8	8.6	8.8	8.1	7.5	8.5
1934	8.8	10.1	10.6	10.6	10.7	10.4	11.8	10.6	11.6	10.8	10.6	10.3	10.6
1935	11.4	13.0	14.5	16.2	15.5	15.3	13.2	12.6	14.1	14.5	14.7	14.8	14.5
1936	15.4	16.8	16.3	16.8	16.2	16.0	15.2	14.2	13.5	12.7	12.1	11.3	15.4
1937	12.8	13.2	14.8	15.1	14.6	14.7	15.2	16.4	16.9	16.6	15.9	15.4	15.1
1938	16.4	15.6	15.7	15.9	15.4	15.6	14.9	12.7	13.4	12.1	12.6	12.6	14.8
1939	13.3	14.0	14.2	13.7	13.0	12.5	12.9	12.0	13.0	12.0	11.4	10.7	13.1

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 43. Chickens. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	53	56	58	60	61	62	60	57	56	54	51	49	58
1911	50	50	51	53	54	56	56	53	52	50	45	42	52
1912	44	48	50	51	51	52	54	53	53	54	51	50	51
1913	50	52	55	57	58	62	68	64	58	56	53	49	57
1914	52	58	58	63	61	59	70	62	62	56	50	48	58
1915	50	55	54	56	54	60	62	58	56	55	50	50	56
1916	52	56	60	64	64	76	75	70	68	67	64	62	64
1917	68	74	78	88	88	90	92	84	92	91	82	80	84
1918	85	97	90	92	96	100	110	110	110	103	102	90	98
1919	98	102	112	125	130	130	140	130	115	110	100	100	118
1920	108	124	126	136	130	125	142	132	125	125	115	95	127
1921	100	105	110	105	100	95	100	100	85	85	80	80	100
1922	85	95	95	95	95	110	100	90	85	85	80	80	93
1923	82	87	90	90	95	100	105	96	95	90	80	75	92
1924	76	85	90	93	93	102	97	105	94	89	87	84	92
1925	89	94	99	106	110	106	112	105	99	95	88	89	101
1926	98	104	107	114	122	124	117	112	104	98	91	89	109
1927	94	98	104	104	107	103	103	97	94	94	92	89	100
1928	91	96	96	100	101	110	116	110	112	110	104	100	102
1929	104	108	112	118	122	126	124	110	107	104	97	90	112
1930	95	99	103	106	90	92	85	79	78	84	72	69	92
1931	72	70	77	81	75	80	78	82	78	68	67	68	76
1932	66	59	59	60	56	56	54	51	50	48	42	38	55
1933	39	42	38	43	46	43	48	44	43	44	40	38	42
1934	44	50	53	53	54	52	59	53	58	54	53	52	53
1935	57	65	72	81	78	76	66	63	70	72	74	74	72
1936	77	84	82	84	81	80	76	71	68	64	60	56	77
1937	64	66	74	76	73	74	76	82	84	83	80	77	76
1938	82	78	78	80	77	78	74	64	67	60	63	63	74
1939	66	70	71	68	65	62	64	60	65	60	57	54	66

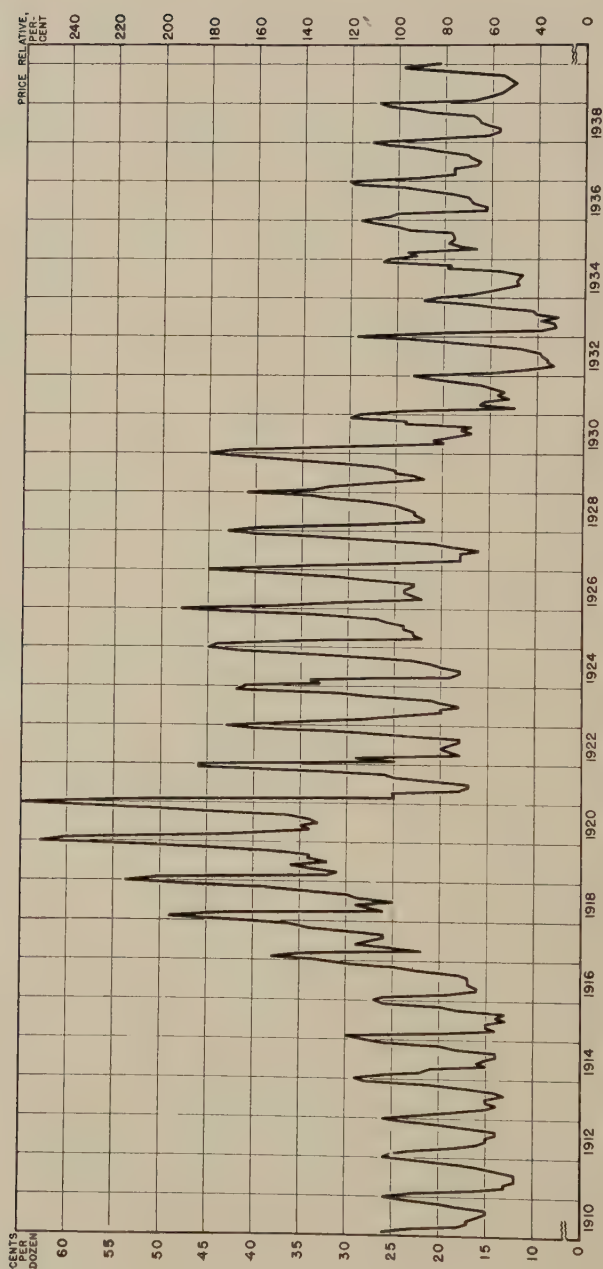


Figure 20. Eggs. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Egg prices have exhibited a distinctive seasonal movement each year. Over this period there has been a wide range of prices, from 260 percent of the 1921-1929 average in December, 1920, to 31 percent in June, 1933. The high prices come at seasons of relatively low production and lower prices at seasons of heavy production.

Table 44. Eggs. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (cents per dozen).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	26	23	18	17	17	16	15	15	18	20	24	26	18
1911	23	16	13	13	12	12	12	14	16	18	22	26	15
1912	25	23	18	16	15	15	14	14	17	20	24	26	17
1913	22	18	15	14	15	15	13	14	17	21	28	29	17
1914	26	22	21	15	16	15	14	14	18	20	26	28	18
1915	30	20	14	15	15	13	14	13	18	20	26	27	17
1916	26	19	16	16	17	17	17	18	22	25	30	33	19
1917	38	35	22	26	29	27	26	26	31	34	36	42	29
1918	49	44	26	28	29	25	29	30	35	39	48	54	32
1919	50	32	31	34	36	32	34	34	37	45	52	63	37
1920	60	43	38	34	35	33	34	36	44	50	57	65	40
1921	50	25	25	18	17	17	21	25	26	32	46	46	25
1922	25	29	18	19	20	19	18	18	24	30	40	43	22
1923	35	28	24	20	20	18	20	21	27	31	42	41	24
1924	33	34	19	18	18	20	21	23	28	34	42	45	24
1925	44	35	22	23	23	24	24	26	27	32	43	48	27
1926	36	30	22	23	24	24	23	23	28	31	37	45	26
1927	35	25	18	18	18	16	19	21	27	33	40	43	23
1928	39	29	22	22	23	23	24	25	28	32	34	41	26
1929	34	32	27	22	23	25	25	27	31	36	41	45	28
1930	42	31	20	21	19	17	18	17	24	24	30	29	22
1931	25	13	16.3	15.6	12.9	14.2	13.4	14.9	16.0	18.7	21.6	23.2	15.8
1932	15.1	11.3	8.3	9.0	8.9	9.4	9.7	11.4	14.5	18.4	23.2	29.2	11.9
1933	21.0	9.8	7.9	8.3	9.7	7.7	10.3	10.6	14.4	17.4	22.2	20.7	11.4
1934	17.0	15.2	13.7	12.1	12.3	11.9	11.8	14.0	19.7	19.2	26.4	26.0	14.9
1935	23.0	24.0	16.4	18.7	19.4	19.0	19.0	19.3	23.9	25.3	27.5	29.1	20.7
1936	25.7	24.9	15.6	15.6	17.1	17.2	17.6	19.2	22.1	24.6	29.8	30.3	19.6
1937	22.9	19.0	19.1	19.1	16.6	16.2	17.2	17.8	20.4	22.3	26.3	27.8	19.2
1938	20.9	15.3	14.3	14.2	15.4	16.2	16.6	17.1	21.7	23.4	26.3	27.1	17.6
1939	16.7	15.2	14.0	13.4	13.1	12.4	12.9	13.6	17.6	20.7	24.5	20.8	15.0

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 45. Eggs. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	104	92	72	68	68	64	60	60	72	80	96	104	72
1911	92	64	52	52	48	48	48	56	64	72	88	104	60
1912	100	92	72	64	60	60	56	56	68	80	96	104	68
1913	88	72	60	56	60	50	52	56	68	84	112	116	68
1914	104	88	84	60	64	60	56	56	72	80	104	112	72
1915	120	80	56	60	60	52	56	52	72	80	104	108	68
1916	104	76	64	64	68	68	68	72	88	100	120	132	76
1917	152	140	88	104	116	108	104	104	124	136	144	168	116
1918	196	176	104	112	116	100	116	120	140	156	192	216	128
1919	200	128	124	136	144	128	136	136	148	180	208	252	148
1920	240	172	152	136	140	132	136	144	176	200	228	260	160
1921	200	100	100	72	68	68	84	100	104	128	184	184	100
1922	100	116	72	76	80	76	72	72	96	120	160	172	88
1923	140	112	96	80	80	72	80	84	108	124	168	164	96
1924	132	136	76	72	72	80	84	92	112	136	168	180	96
1925	176	140	88	92	92	96	96	104	108	128	172	192	108
1926	144	120	88	92	96	96	92	92	112	124	148	180	104
1927	140	100	72	72	72	64	76	84	108	132	160	172	92
1928	156	116	88	88	92	92	96	100	112	128	136	164	104
1929	136	128	108	88	92	100	100	108	124	144	164	180	112
1930	168	124	80	84	76	68	72	68	96	96	120	116	88
1931	100	52	65	62	52	57	54	60	64	75	86	93	63
1932	60	45	33	36	36	38	39	46	58	74	93	117	48
1933	84	39	32	33	39	31	41	42	58	70	89	83	46
1934	68	61	55	48	49	48	47	56	79	77	106	104	60
1935	92	96	66	75	78	76	76	77	96	101	110	116	83
1936	103	100	62	62	68	69	70	77	88	98	119	121	78
1937	92	76	76	76	66	65	69	71	82	89	105	111	77
1938	84	61	57	57	62	65	66	68	87	94	105	108	70
1939	67	61	56	54	52	50	52	54	70	83	98	83	60

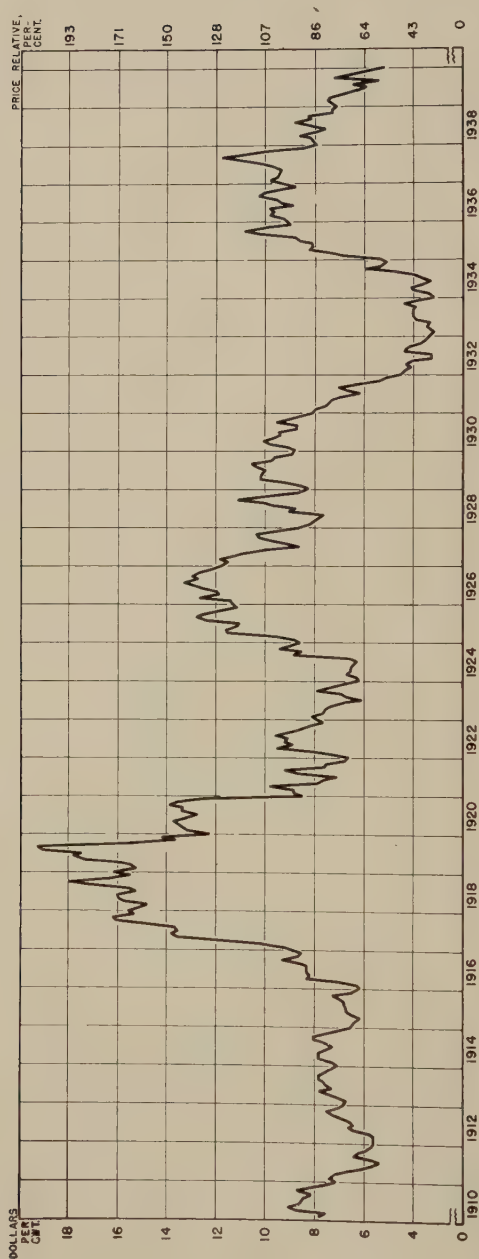


Figure 21. Hogs. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices in 1918 and 1919 were nearly double those that prevailed during the twenties. Highest prices of the twenties occurred in 1925 and 1926 while prices of other livestock did not reach their peak in this period until 1928 and 1929. From 1932 to 1934, hog prices were well below prewar levels but after that they recovered more than most farm products.

Table 46. Hogs. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per 100 pounds).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	7.80	7.60	8.80	9.10	8.60	8.50	8.40	8.10	8.70	8.40	7.60	7.10	8.31
1911	7.40	7.20	6.70	6.10	5.60	5.40	5.80	6.40	6.30	5.90	5.70	5.60	6.09
1912	5.60	5.60	5.80	6.40	6.60	6.40	6.50	7.00	7.30	7.50	7.00	6.80	6.62
1913	6.70	7.00	7.50	7.80	7.30	7.60	7.70	7.80	7.80	7.60	7.40	7.10	7.49
1914	7.30	7.80	7.80	7.80	7.50	7.30	7.60	8.00	8.00	7.60	7.00	6.50	7.55
1915	6.40	6.30	6.20	6.50	6.70	6.70	6.80	6.80	7.00	7.30	6.40	6.20	6.65
1916	6.30	7.00	8.30	8.20	8.30	8.30	8.30	8.60	9.30	8.60	8.50	9.00	8.32
1917	9.20	10.30	12.30	13.50	13.80	13.50	13.60	14.80	16.10	16.20	15.30	15.60	13.95
1918	15.10	14.80	15.80	16.00	16.00	15.20	15.50	17.20	17.90	16.20	15.50	16.20	16.03
1919	15.20	15.40	16.10	17.40	17.70	17.50	19.10	19.30	15.50	13.60	14.20	12.20	16.31
1920	13.20	13.40	13.50	13.70	13.20	12.70	13.40	13.40	13.90	13.50	12.40	8.50	13.01
1921	8.80	8.90	9.80	7.80	7.70	7.10	8.70	9.20	7.60	7.50	6.70	6.60	7.99
1922	7.30	8.50	9.50	8.90	9.20	9.10	9.60	9.00	8.60	8.20	7.70	7.90	8.71
1923	8.10	7.70	7.60	7.40	6.80	6.10	6.70	6.90	7.90	7.20	6.70	6.20	7.07
1924	6.30	6.70	6.50	6.50	6.40	6.30	6.50	8.90	8.50	9.50	8.90	8.60	7.50
1925	8.90	9.50	11.60	11.60	11.10	11.00	12.40	12.80	12.50	11.80	11.10	11.30	11.45
1926	11.40	12.70	11.90	12.00	12.60	12.90	13.40	12.70	13.00	12.70	12.10	11.80	12.48
1927	11.50	11.90	11.30	10.90	10.00	8.60	9.10	9.80	10.30	10.40	9.30	8.60	10.08
1928	8.20	7.90	7.70	7.70	9.10	8.80	9.70	10.00	11.10	9.70	8.60	8.20	8.98
1929	8.50	9.10	10.20	10.20	10.10	10.00	10.40	10.60	9.70	9.50	8.90	8.80	9.77
1930	9.10	9.80	10.10	9.70	9.30	9.40	8.70	8.70	9.50	9.10	8.60	8.00	9.19
1931	7.90	7.60	7.40	7.30	6.90	6.20	6.70	7.00	6.30	5.30	5.00	4.50	6.49
1932	4.40	4.10	4.30	4.00	3.30	3.30	4.40	4.30	4.05	3.60	3.45	3.40	3.84
1933	3.15	3.35	3.45	3.40	3.90	4.05	4.05	4.05	3.95	4.40	3.85	3.15	3.79
1934	3.35	4.05	4.15	3.60	3.35	3.60	4.05	4.75	6.00	5.30	5.10	5.30	4.38
1935	6.90	7.40	8.20	8.10	8.10	8.60	8.80	10.30	10.80	10.00	9.00	9.10	8.88
1936	9.20	9.80	9.60	9.80	8.90	9.30	9.50	10.30	10.00	9.40	8.80	9.40	9.49
1937	9.80	9.50	9.40	9.30	9.60	10.10	11.10	11.80	11.00	10.10	8.40	7.90	9.89
1938	8.00	8.10	8.60	8.00	7.60	8.10	8.80	8.10	8.20	7.30	7.30	7.10	7.92
1939	7.30	7.50	7.40	6.70	6.30	5.90	6.40	5.40	7.20	6.60	5.90	5.10	6.43

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 47. Hogs. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	84	81	94	97	92	91	90	87	93	90	81	76	89
1911	79	77	72	65	60	58	62	69	67	63	61	60	65
1912	60	60	62	69	71	69	70	75	78	80	75	73	71
1913	72	75	80	84	78	81	82	84	84	81	79	76	80
1914	78	84	84	84	80	78	81	86	86	81	75	70	81
1915	69	67	66	70	72	72	73	73	75	78	69	66	71
1916	67	75	89	88	89	89	89	92	100	92	91	96	89
1917	99	110	132	145	148	145	146	158	172	173	164	167	149
1918	162	158	169	171	171	163	166	184	192	173	166	173	172
1919	163	165	172	186	190	187	204	207	166	146	152	131	175
1920	141	143	145	147	141	136	143	143	149	145	133	91	139
1921	94	95	105	84	82	76	93	99	81	80	72	71	86
1922	78	91	102	95	99	97	103	96	92	88	82	85	93
1923	87	82	81	79	73	65	72	74	85	77	72	66	76
1924	67	72	70	70	69	67	70	95	91	102	95	92	80
1925	95	102	124	124	119	118	133	137	134	126	119	121	123
1926	122	136	127	128	135	138	143	136	139	136	130	126	134
1927	123	127	121	117	107	92	97	105	110	111	100	92	108
1928	88	85	82	82	97	94	104	107	119	104	92	88	96
1929	91	97	109	109	108	107	111	113	104	102	95	94	105
1930	97	105	108	104	100	101	93	93	102	97	92	86	98
1931	85	81	79	78	74	66	72	75	67	57	54	48	69
1932	47	44	46	43	35	35	47	46	43	39	37	36	41
1933	34	36	37	36	42	43	43	43	42	47	41	34	41
1934	36	43	44	39	36	39	43	51	64	57	55	57	47
1935	74	79	88	87	87	92	94	110	116	107	96	97	95
1936	99	105	103	105	95	100	102	110	107	101	94	101	102
1937	105	102	101	100	103	108	119	126	118	108	90	85	106
1938	86	87	92	86	81	87	94	87	88	78	78	76	85
1939	78	80	79	72	67	63	69	58	77	71	63	55	69

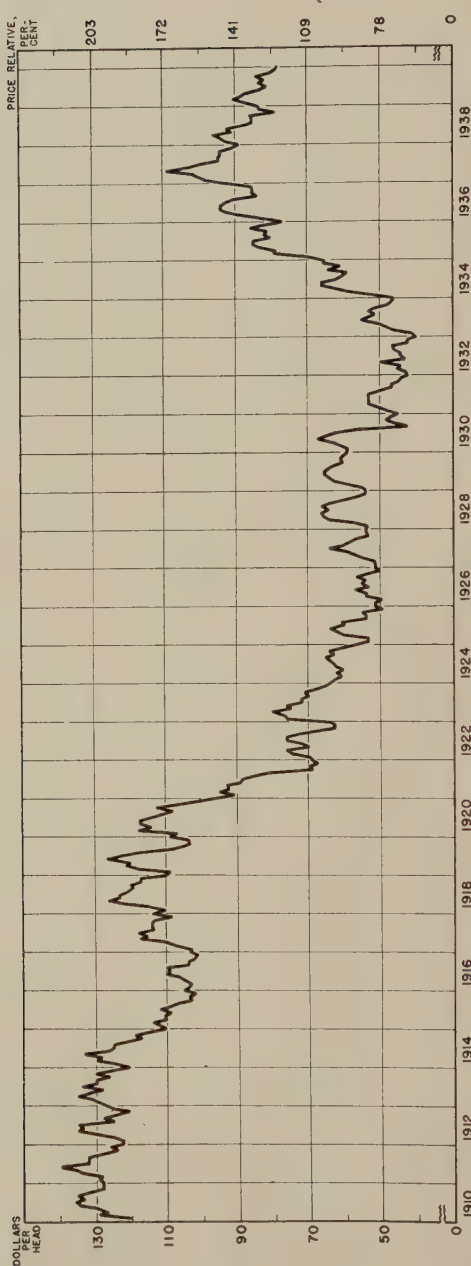


Figure 22. Horses. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

The long-time cyclical movement of horse prices was at its peak in 1910 to 1914. Even war-time prices did not completely overcome the down swing from this high level. A rising general price level and a distinct shortage of horses resulted in a sharp advance in horse prices after 1932. The period from 1921 to 1929 is one of relatively low prices for horses. Prices were seasonally high during the spring and summer and lower during the winter.

Table 48. Horses. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per head).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	120	129	127	129	135	136	133	135	132	128	128	128	128
1911	129	128	134	136	140	132	132	132	128	124	126	122	130
1912	122	125	130	135	134	135	125	128	125	121	125	127	127
1913	129	131	135	132	128	134	130	130	126	130	125	120	130
1914	124	130	128	133	126	125	125	121	117	119	114	110	124
1915	112	114	110	111	109	112	109	107	103	104	102	105	109
1916	104	103	105	106	110	109	110	104	104	102	101	103	104
1917	104	107	110	117	115	118	113	114	114	113	108	114	110
1918	110	114	121	126	123	123	120	119	120	117	117	110	117
1919	109	118	121	120	126	123	118	109	105	103	104	109	114
1920	107	118	114	117	117	114	111	108	112	107	102	96	111
1921	90	95	92	93	89	88	85	81	69	70	67	69	85
1922	70	75	76	70	72	76	76	73	68	63	63	64	71
1923	76	77	80	75	76	72	72	70	71	68	65	64	74
1924	63	61	62	60	62	63	64	65	63	64	60	56	62
1925	53	53	60	62	64	60	61	54	54	55	49	51	56
1926	51	49	54	54	57	53	55	54	56	53	50	51	52
1927	51	52	55	57	59	64	60	58	56	53	54	54	54
1928	53	57	64	65	66	64	66	64	60	56	54	54	59
1929	55	59	63	64	65	65	64	62	60	61	60	59	60
1930	59	61	63	67	65	62	57	42	46	48	47	45	57
1931	48	50	53	53	53	53	50	47	47	45	44	42	49
1932	43	45	44	50	43	44	44	46	47	42	42	40	44
1933	41	46	48	50	55	53	51	53	51	48	47	46	47
1934	51	58	62	66	66	62	60	59	64	61	65	65	61
1935	70	79	79	83	85	85	80	82	81	86	82	77	79
1936	82	88	92	94	94	93	90	84	85	85	86	92	88
1937	98	100	102	109	103	100	95	95	94	94	91	89	98
1938	93	94	96	91	92	87	85	85	86	79	83	84	90
1939	87	90	88	87	83	81	83	82	84	80	79	78	85

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 49. Horses. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	188	202	198	202	211	212	208	211	206	200	200	200	200
1911	202	200	209	212	219	206	206	206	200	194	197	191	203
1912	191	195	203	211	209	211	195	200	195	189	195	198	198
1913	202	205	211	206	200	209	203	203	197	203	195	188	203
1914	194	203	200	208	197	195	195	189	183	186	178	172	194
1915	175	178	172	173	170	175	170	167	161	162	159	164	170
1916	162	161	164	166	172	170	172	162	162	159	158	161	162
1917	162	167	172	183	180	184	177	178	178	177	169	178	172
1918	172	178	189	197	192	192	188	186	187	183	183	172	183
1919	170	184	189	188	197	192	184	170	164	161	162	170	178
1920	167	184	178	183	183	178	173	169	175	167	159	150	173
1921	141	148	144	145	139	138	133	127	108	109	105	108	133
1922	109	117	119	109	112	119	119	114	106	98	98	100	111
1923	119	120	125	117	119	112	112	109	111	106	102	100	116
1924	98	95	97	94	97	98	100	102	98	100	94	88	97
1925	83	83	94	97	100	94	95	84	84	86	77	80	88
1926	80	77	84	84	89	83	86	84	88	83	78	80	81
1927	80	81	86	89	92	100	94	91	88	83	84	84	84
1928	83	89	100	102	103	100	103	100	94	88	84	84	92
1929	86	92	98	100	102	102	100	97	94	95	94	92	94
1930	92	95	98	105	102	97	89	66	72	75	73	70	89
1931	75	78	83	83	83	83	78	73	73	70	69	66	77
1932	67	70	69	78	67	69	69	72	73	66	66	62	69
1933	64	72	75	78	86	83	80	83	80	75	73	72	73
1934	80	91	97	103	103	97	94	92	100	95	102	102	95
1935	109	123	123	130	133	133	125	128	127	134	128	120	123
1936	128	138	144	147	147	145	141	131	133	133	134	144	138
1937	153	156	159	170	161	156	148	148	147	147	142	139	153
1938	145	147	150	142	144	136	133	133	134	123	130	131	141
1939	136	141	138	136	130	127	130	128	131	125	123	122	133

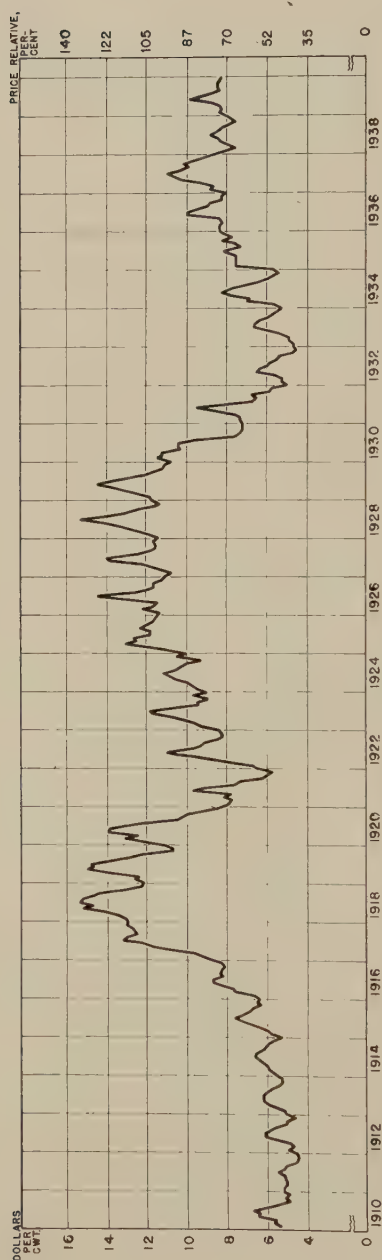


Figure 23. Lambs. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices usually were highest in May or June, when Kentucky lambs move in fairly heavy volume, and lowest in the fall and early winter. The seasonal range in price usually was two or three dollars per hundredweight. Prices during the late twenties were nearly as high as those which prevailed during the World War and were relatively much higher than those of most farm products. Lambs during the depression in 1932, barely reached prewar levels in contrast with prices of many farm products which fell below the prewar level.

Table 50. Lambs. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per 100 pounds).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	5.40	5.70	5.60	6.50	6.40	6.70	5.90	5.50	4.90	5.10	4.90	5.10	5.94
1911	5.10	5.00	5.00	5.20	5.20	5.50	5.10	5.00	4.60	4.50	4.50	4.60	5.11
1912	5.00	4.70	4.90	5.50	6.20	6.20	5.80	5.60	5.00	5.00	4.60	5.00	5.77
1913	5.20	5.60	5.90	6.20	6.20	6.20	6.10	5.70	5.40	5.30	5.30	5.50	5.94
1914	5.70	5.90	6.00	6.20	6.40	6.60	6.50	6.20	6.10	5.90	5.70	5.30	6.37
1915	5.80	6.00	6.30	7.00	7.30	7.70	7.20	6.90	6.80	6.30	6.50	6.40	7.19
1916	6.60	7.50	7.70	8.20	8.70	8.70	8.30	8.40	8.30	8.10	8.20	8.80	8.45
1917	9.20	9.60	10.90	11.70	12.10	13.20	12.90	12.50	12.60	12.70	13.00	12.90	12.79
1918	13.00	13.40	14.10	15.20	14.70	15.40	15.20	14.70	14.30	13.10	12.30	12.10	14.86
1919	12.60	12.40	13.90	15.00	14.70	14.80	13.90	12.90	12.20	10.70	10.70	11.10	13.65
1920	12.40	13.00	12.35	14.00	13.90	13.10	12.10	10.40	10.20	9.50	8.70	8.10	11.82
1921	7.90	7.80	8.10	7.80	9.70	9.10	7.60	7.30	6.20	6.00	5.70	6.50	7.89
1922	6.70	7.90	8.90	10.40	11.00	10.00	9.40	9.20	8.50	8.20	8.30	8.40	9.49
1923	9.30	9.50	10.20	10.70	11.70	11.90	10.70	9.40	9.40	8.90	9.70	9.00	10.63
1924	9.50	9.70	10.00	10.50	11.00	11.20	10.50	10.30	10.00	9.30	10.50	10.10	10.59
1925	11.00	12.00	13.00	12.50	12.60	11.80	11.80	12.40	12.00	11.70	11.60	11.50	11.99
1926	11.30	12.20	11.70	11.40	13.00	14.50	12.60	12.00	11.70	11.70	11.20	11.10	12.86
1927	10.80	11.30	11.80	12.40	13.90	14.00	12.50	11.80	11.60	11.60	11.70	11.40	12.74
1928	11.70	12.30	12.80	13.40	14.30	15.40	14.00	13.00	12.50	11.70	11.30	11.70	13.90
1929	11.80	12.40	13.10	13.50	14.40	14.00	13.00	12.10	11.70	11.20	11.10	10.80	12.96
1930	11.50	11.20	11.20	10.30	10.40	10.40	9.40	7.50	7.30	7.20	7.20	7.20	9.07
1931	7.30	7.30	7.60	8.60	9.50	8.00	6.70	6.50	6.70	5.80	5.70	5.00	7.17
1932	5.30	5.30	5.60	6.50	6.40	5.90	5.80	5.50	5.40	4.65	4.60	4.75	5.70
1933	4.75	4.90	4.90	5.40	6.00	6.60	6.60	6.40	6.00	5.70	5.50	5.30	6.38
1934	5.60	7.00	6.90	7.80	8.30	7.80	7.10	6.40	6.00	5.70	5.40	5.70	7.05
1935	7.50	7.50	7.50	7.60	7.70	8.10	7.30	7.50	8.30	7.80	8.10	8.40	7.72
1936	8.40	8.40	8.20	8.40	10.00	10.00	9.40	8.90	8.80	8.30	8.30	8.00	9.37
1937	8.80	8.70	9.20	10.30	10.60	11.00	10.30	10.00	10.20	9.60	9.10	8.60	10.37
1938	8.10	7.60	8.00	8.40	8.50	8.80	8.50	8.30	8.00	7.50	7.80	8.00	8.44
1939	8.40	8.20	8.40	8.70	9.80	9.40	8.70	8.40	8.50	8.50	8.40	8.20	8.88

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 51. Lambs. Relatives of prices received by Kentucky producers on the 15th of month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	47	50	49	57	56	59	52	48	43	45	43	45	52
1911	45	44	44	45	45	48	45	44	40	39	39	40	45
1912	44	41	43	48	54	54	51	49	44	44	40	44	50
1913	45	49	52	54	54	54	53	50	47	46	46	48	52
1914	50	52	52	54	56	58	57	54	53	52	50	46	56
1915	51	52	55	61	64	67	63	60	59	55	57	56	63
1916	58	66	67	72	76	76	72	73	72	71	72	77	74
1917	80	84	95	102	106	115	113	109	110	111	114	113	112
1918	114	117	123	133	128	134	133	128	125	114	107	106	130
1919	110	108	121	131	128	129	121	113	107	93	93	97	119
1920	108	114	108	122	121	114	106	91	89	83	76	71	103
1921	69	68	71	68	85	79	66	64	54	52	50	57	69
1922	59	69	78	91	96	87	82	80	74	72	72	73	83
1923	81	83	89	93	102	104	93	82	82	78	85	79	93
1924	83	85	87	92	96	98	92	90	87	81	92	88	92
1925	96	105	114	109	110	103	103	108	105	102	101	100	105
1926	99	107	102	100	114	127	110	105	102	102	98	97	112
1927	94	99	103	108	121	122	109	103	101	101	102	100	111
1928	102	107	112	117	125	134	122	114	109	102	99	102	121
1929	103	108	114	118	126	122	114	106	102	98	97	94	113
1930	100	98	98	90	91	91	82	66	64	63	63	63	79
1931	64	64	66	75	83	70	59	57	59	51	50	44	63
1932	46	46	49	57	56	52	51	48	47	41	40	41	50
1933	41	43	43	47	52	58	58	56	52	50	48	46	56
1934	49	61	60	68	72	68	62	56	52	50	47	50	62
1935	66	66	66	66	67	71	64	66	72	68	71	73	67
1936	73	73	72	73	87	87	82	78	77	72	72	70	82
1937	77	76	80	90	93	96	90	87	89	84	79	75	91
1938	71	66	70	73	74	77	74	72	70	66	68	70	74
1939	73	72	73	76	86	82	76	73	74	74	73	72	78

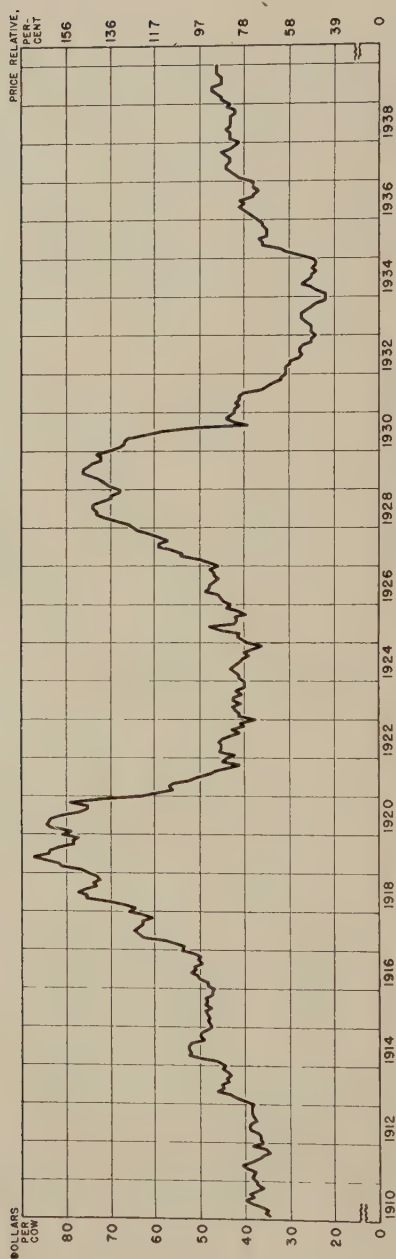


Figure 24. Milk cows. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices during the late twenties were nearly as high as during 1918, 1919 and 1920. From 1922 to 1926 prices were at essentially prewar levels and in 1932, 1933 and 1934, they were even lower. The base period, 1921-29, is one of rather marked change in the price of dairy cows. Seasonally, prices in the spring usually have been higher than in fall and winter.

Table 52. Milk cows. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per head).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1935	35	36	35	36	38	40	38	39	38	36	38	38	37
1936	39	38	38	40	41	39	37	36	34	35	37	36	37
1937	37	37	37	38	39	39	38	38	38	38	39	38	38
1938	40	42	43	46	44	45	44	44	43	44	45	44	44
1939	46	50	52	52	52	52	52	49	50	50	48	47	50
1940	48	48	48	48	49	47	49	48	49	47	47	47	48
1941	48	48	50	50	52	51	51	50	50	50	51	54	50
1942	54	55	58	63	64	65	64	62	63	61	63	66	61
1943	64	67	70	76	76	78	75	73	74	72	73	75	72
1944	77	81	82	85	88	84	84	82	78	79	77	81	81
1945	79	83	84	84	83	82	77	75	75	79	73	64	78
1946	60	56	57	56	52	51	48	46	44	41	45	44	50
1947	42	46	45	45	46	45	43	41	43	40	41	38	43
1948	41	41	42	43	41	42	43	40	42	40	40	40	41
1949	41	41	42	43	42	41	40	39	40	38	36	39	40
1950	41	42	41	45	48	42	41	42	40	42	44	43	42
1951	45	46	46	49	48	48	47	46	47	47	48	46	47
1952	48	50	54	54	56	59	59	57	59	61	64	65	56
1953	66	68	71	73	73	74	74	72	70	70	68	68	70
1954	70	71	72	74	76	76	75	74	72	72	73	70	72
1955	68	67	67	66	62	59	52	39	42	44	43	42	54
1956	42	41	42	41	41	40	36	35	34	32	32	31	37
1957	31	31	30	30	28	27	28	28	27	25	25	24	28
1958	25	25	25	26	27	27	27	26	25	24	22	22	25
1959	22	24	25	27	26	25	25	24	25	24	24	25	25
1960	28	31	32	36	36	37	35	35	35	36	36	37	34
1961	38	39	40	41	40	41	39	38	37	38	38	38	39
1962	41	42	43	44	44	43	43	44	45	43	42	41	43
1963	43	43	43	44	43	43	43	43	42	42	44	43	43
1964	45	45	46	47	47	45	45	45	46	46	46	46	46

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.
For calendar year, weighted by average monthly marketings of 1926-1930.

Table 53. Milk Cows. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	67	69	68	71	75	78	74	76	73	70	73	73	72
1911	75	74	73	77	79	75	72	70	67	69	75	70	72
1912	71	71	72	75	76	75	73	74	75	75	75	74	73
1913	78	82	84	90	87	88	85	86	84	85	88	86	85
1914	89	96	102	101	102	102	101	95	97	97	94	92	97
1915	93	94	93	94	95	92	95	94	95	92	92	91	94
1916	94	94	97	98	101	99	100	96	98	97	100	105	97
1917	104	107	113	122	124	126	124	122	122	118	123	129	118
1918	125	130	137	147	147	151	147	142	144	141	142	146	140
1919	149	158	159	165	170	163	163	159	152	153	150	158	158
1920	153	162	164	163	162	158	150	146	146	154	142	124	152
1921	117	109	111	109	102	99	93	90	85	80	88	86	98
1922	82	89	88	88	89	88	84	80	84	78	80	73	83
1923	80	80	82	83	79	83	83	79	82	78	78	78	80
1924	80	80	82	84	82	80	79	76	78	74	70	76	78
1925	79	81	80	88	93	82	81	82	77	81	86	84	82
1926	87	88	89	95	93	93	91	89	91	91	93	89	91
1927	93	97	105	105	109	115	115	111	115	119	124	126	110
1928	128	132	138	142	142	144	144	140	136	136	132	132	137
1929	136	138	140	144	148	148	146	144	140	140	142	136	141
1930	132	130	130	128	121	115	101	76	82	86	84	82	105
1931	82	80	82	80	80	78	70	68	66	62	62	60	73
1932	60	60	58	58	54	53	54	54	53	49	49	47	55
1933	49	49	49	51	53	53	53	51	49	47	43	43	49
1934	43	47	49	53	51	49	49	47	49	47	47	49	48
1935	54	60	62	70	70	72	68	68	68	70	70	72	66
1936	74	76	78	80	78	80	74	74	72	74	74	74	75
1937	80	82	84	86	86	84	84	86	88	84	82	80	84
1938	84	84	84	86	84	84	84	84	82	82	86	84	84
1939	88	88	90	92	92	88	88	88	90	90	90	90	90

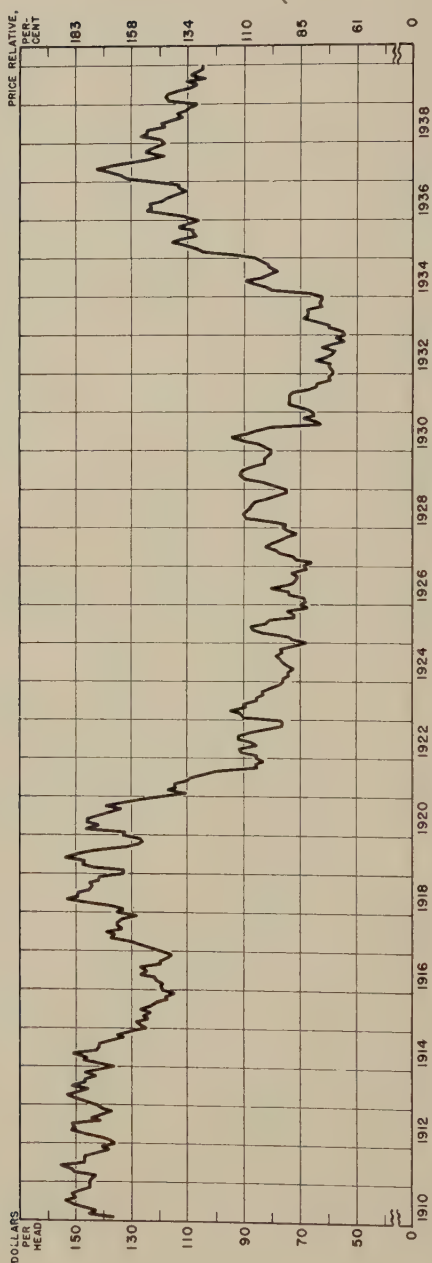


Figure 25. Mules. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

The long-time cyclical movement of mules prices was at its peak in 1910 to 1914. Even war-time prices did not completely overcome the down swing from this high level. A rising general price level and a distinct shortage of mules resulted in a sharp advance in prices after 1932. The period of 1921-1929 is one of relatively low prices for mules. Prices have been seasonally high during the spring and summer and lower during the winter.

Table 54. Mules. Prices received by Kentucky producers on the 15th of the month, 1910-1939 (dollars per head).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
1910	136	146	143	146	152	154	150	152	149	145	145	145	145
1911	144	143	150	152	156	147	147	147	143	138	141	136	145
1912	138	141	147	152	151	152	141	144	141	137	141	143	143
1913	146	149	153	150	145	152	147	147	143	147	142	136	147
1914	141	148	146	151	143	142	142	138	133	135	130	125	141
1915	127	129	124	126	123	127	123	121	117	118	115	119	123
1916	120	119	121	122	127	125	127	120	120	117	116	119	120
1917	123	126	130	138	136	139	134	135	135	134	128	135	130
1918	133	138	147	153	149	149	145	144	145	142	142	133	142
1919	133	144	148	147	154	150	144	133	128	126	127	133	139
1920	133	147	142	146	146	142	138	134	139	133	127	120	138
1921	111	117	114	115	110	109	105	100	85	86	83	85	105
1922	85	91	92	85	87	92	92	88	82	76	76	77	85
1923	90	91	95	89	90	85	85	83	84	80	77	76	87
1924	76	74	75	72	75	76	77	79	76	77	72	68	74
1925	73	74	83	87	88	82	81	72	72	75	67	70	77
1926	68	69	74	74	80	75	72	71	71	73	67	69	71
1927	66	71	73	78	79	82	80	77	75	71	75	76	73
1928	75	81	89	90	89	88	87	86	81	78	75	75	82
1929	79	84	89	91	91	90	87	82	83	82	80	80	84
1930	83	85	90	94	89	85	80	62	64	69	65	66	80
1931	67	74	74	74	74	73	67	64	64	59	60	58	68
1932	58	60	59	65	61	58	57	62	59	54	57	54	59
1933	55	60	60	65	69	67	67	62	63	62	62	62	61
1934	67	80	82	87	89	84	80	78	81	81	84	86	80
1935	94	105	107	111	116	112	107	108	108	113	110	106	106
1936	110	117	125	123	124	119	117	114	111	113	113	124	118
1937	132	134	138	143	138	130	124	119	125	124	121	118	131
1938	120	127	125	125	118	120	116	112	114	111	109	107	119
1939	117	118	117	114	109	107	111	103	108	106	104	104	112

¹ Monthly prices, 1910-1924, are estimated on the basis of the December 1 farm price of mules and the seasonal movement of the prices of horses. Prices for 1925 and later years are from "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of 1926-1930.

Table 55. Mules. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1910	166	178	174	178	185	188	183	185	182	177	177	177	177
1911	176	174	183	185	190	179	179	179	174	168	172	166	177
1912	168	172	179	185	184	185	172	176	172	167	172	174	174
1913	178	182	187	183	177	185	179	179	174	179	173	166	179
1914	172	180	178	184	174	173	173	168	162	165	159	152	172
1915	155	157	151	154	150	155	150	148	143	144	140	145	150
1916	146	145	148	149	155	152	155	146	146	143	141	145	146
1917	150	154	159	168	166	170	163	165	165	163	156	165	159
1918	162	168	179	187	182	182	177	176	177	173	173	162	173
1919	162	176	180	179	188	183	176	162	156	154	155	162	170
1920	162	179	173	178	178	173	168	163	170	162	155	146	168
1921	135	143	139	140	134	133	128	122	104	105	101	104	128
1922	104	111	112	104	106	112	112	107	100	93	93	94	104
1923	110	111	116	109	110	104	104	101	102	98	94	93	106
1924	93	90	91	88	91	93	94	96	93	94	88	83	90
1925	89	90	101	106	107	100	99	88	88	91	82	85	94
1926	83	84	90	90	98	91	88	87	87	89	82	84	87
1927	80	87	89	95	96	100	98	94	91	87	91	93	89
1928	91	99	109	110	109	107	106	105	99	95	91	91	100
1929	96	102	109	111	111	110	106	100	101	100	98	98	102
1930	101	104	110	115	109	104	98	76	78	84	79	80	98
1931	82	90	90	90	90	89	82	78	78	72	73	71	83
1932	71	73	72	79	74	71	70	76	72	66	70	66	72
1933	67	73	73	79	84	82	82	82	76	77	76	76	74
1934	82	98	100	106	109	102	98	95	99	99	102	105	98
1935	115	128	130	135	141	137	130	132	132	138	134	129	129
1936	134	143	152	150	151	145	143	139	135	138	138	151	144
1937	161	163	168	174	168	159	151	145	152	151	148	144	160
1938	146	155	152	152	144	146	141	137	139	135	133	130	145
1939	143	144	143	139	133	130	135	126	132	129	127	127	137

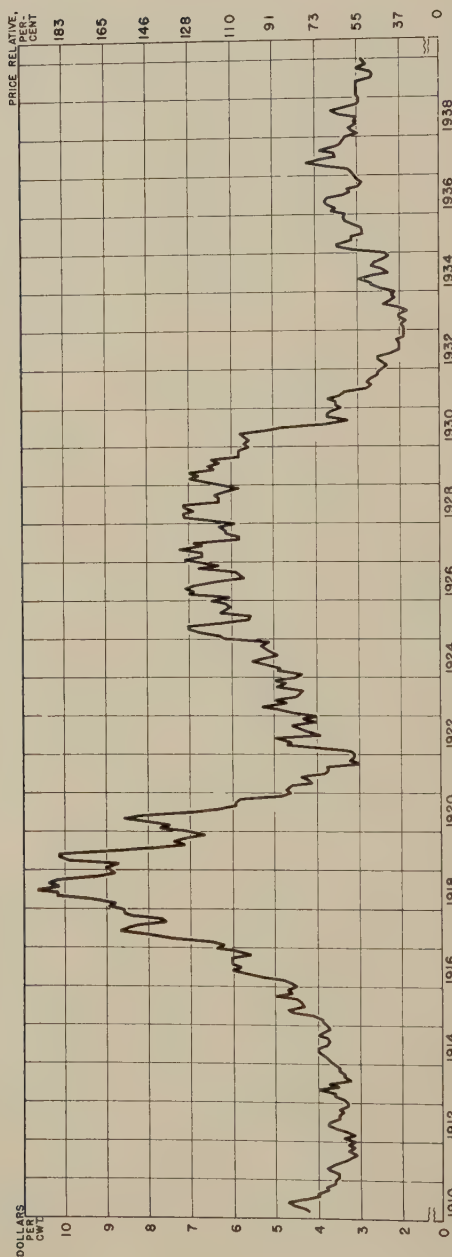


Figure 26. Sheep. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

The seasonal price pattern for sheep is not so clearly defined as that for lambs. Prices in 1918 and 1919 were about 50 percent higher than in the late twenties. Since the depth of the late depression, prices have risen but little and during the past two years have averaged about 55 percent of prices during the base period, 1921-1929.

Table 56. Sheep. Prices received by Kentucky producers on the 15th of the month, 1910- (dollars per 100 pounds).¹

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
4.30	4.20	4.30	4.60	4.70	4.30	4.00	4.00	3.80	3.80	3.60	3.60	4.09
3.50	3.50	3.70	3.80	3.60	3.40	3.20	3.10	3.30	3.10	3.30	3.10	3.29
3.40	3.10	3.30	3.60	3.80	3.70	3.50	3.50	3.40	3.50	3.30	3.30	3.53
3.40	3.60	3.60	4.00	3.50	3.70	3.20	3.40	3.40	3.50	3.50	3.60	3.47
3.70	3.80	3.90	4.00	4.00	3.80	3.70	3.80	4.00	3.90	3.70	3.80	3.86
3.90	3.90	4.10	4.60	4.70	4.30	4.40	4.50	5.00	4.60	4.70	4.50	4.56
4.60	4.80	5.30	5.70	6.00	5.80	6.00	6.00	6.00	5.60	5.90	6.40	5.87
6.20	6.50	7.50	8.00	8.70	8.60	8.20	7.60	7.70	8.40	8.60	8.60	8.05
8.90	8.80	9.30	10.20	10.20	10.60	10.10	10.40	10.20	9.30	8.80	8.90	10.05
9.00	8.70	9.90	10.10	10.10	8.90	7.90	7.10	7.40	7.10	6.60	7.00	8.03
7.70	7.50	8.00	8.60	8.20	6.90	6.30	5.90	5.90	5.80	4.80	4.60	6.49
4.70	4.60	4.10	4.20	4.40	3.80	3.70	3.70	3.00	3.20	3.10	3.10	3.66
3.20	4.00	4.70	4.60	5.00	3.90	4.20	4.40	4.60	4.00	4.30	4.00	4.36
4.60	4.90	5.30	4.70	5.00	4.50	4.40	4.30	5.00	4.70	5.00	4.50	4.65
4.30	4.90	4.80	5.20	5.50	5.20	4.90	5.10	5.20	5.30	5.10	6.20	5.18
6.30	6.80	7.00	7.00	6.20	5.60	5.50	6.30	6.10	6.00	6.10	6.50	6.09
6.00	7.00	6.90	7.10	6.80	6.30	5.70	5.80	5.90	6.80	6.30	6.80	6.24
7.10	6.70	6.70	7.20	6.70	6.90	5.80	5.80	6.10	6.10	6.30	5.90	6.23
6.50	7.10	7.10	6.90	7.10	7.10	6.30	6.30	6.40	6.10	5.80	6.20	6.52
6.60	7.00	6.80	7.00	6.40	6.50	6.30	6.50	5.80	5.80	5.80	5.60	6.27
5.70	5.60	5.70	5.80	5.20	4.80	3.80	3.20	3.70	3.70	3.60	3.40	4.08
3.50	3.50	3.70	3.40	3.30	2.80	2.70	2.80	2.70	2.50	2.50	2.40	2.85
2.30	2.40	2.50	2.50	2.20	2.00	2.00	2.00	2.10	1.90	1.90	1.90	2.06
1.90	1.95	1.85	2.00	2.00	1.80	2.00	2.40	2.25	2.15	2.20	2.15	2.13
2.45	2.70	2.70	2.95	2.70	2.25	2.40	2.70	2.60	2.40	2.25	2.35	2.55
3.05	3.45	3.45	3.10	3.10	2.85	2.85	2.90	3.10	3.30	3.35	3.30	3.04
3.60	3.50	3.70	3.80	3.70	3.35	3.15	3.25	2.95	2.90	3.00	3.05	3.24
3.10	3.20	3.75	4.20	3.90	3.50	3.55	3.90	3.55	3.40	3.35	3.30	3.66
2.95	3.10	3.15	3.00	3.05	3.00	3.45	3.60	3.20	3.00	2.95	2.95	3.24
3.00	3.00	3.00	3.00	3.00	2.70	2.65	2.70	3.00	2.80	2.85	2.90	2.82

¹Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.
²For calendar year, weighted by average monthly marketings of 1926-1930.

Table 57. Sheep. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
79	77	79	84	86	79	73	73	69	69	66	66	75
64	64	68	69	66	62	59	57	60	57	60	57	60
62	57	60	66	69	68	64	64	62	64	60	60	65
62	66	66	73	64	68	59	62	62	64	64	66	63
68	69	71	73	73	69	68	69	73	71	68	69	71
71	71	75	84	86	79	80	82	91	84	86	82	83
84	88	97	104	110	106	110	110	110	102	108	117	107
113	119	137	146	159	157	150	139	141	154	157	157	147
163	161	170	186	186	194	185	190	186	170	161	163	184
165	159	181	185	185	163	144	130	135	130	121	128	147
141	137	146	157	150	126	115	108	108	106	88	84	119
86	84	75	77	80	69	68	68	55	59	57	57	67
59	73	86	84	91	71	77	80	84	73	79	73	80
84	90	97	86	91	82	80	79	91	86	91	82	85
79	90	88	95	101	95	90	93	95	97	93	113	95
115	124	128	128	113	102	101	115	112	110	112	119	111
110	128	126	130	124	115	104	106	108	124	115	124	114
130	122	122	132	122	126	106	106	112	112	115	108	114
119	130	130	126	130	130	115	115	117	112	106	113	119
121	128	124	128	117	119	115	119	106	106	106	102	115
104	102	104	106	95	88	69	59	68	68	66	62	75
64	64	68	62	60	51	49	51	49	46	46	44	52
42	44	46	46	40	37	37	37	38	35	35	35	38
35	36	34	37	37	33	37	44	41	39	40	39	39
45	49	49	54	49	41	44	49	48	44	41	43	47
56	63	63	57	57	52	52	53	57	60	61	60	56
66	64	68	69	68	61	58	59	54	53	55	56	59
57	59	69	77	71	64	65	71	65	62	61	60	67
54	57	58	55	56	55	63	66	59	55	54	54	59
55	55	55	55	55	49	48	49	55	51	52	53	52

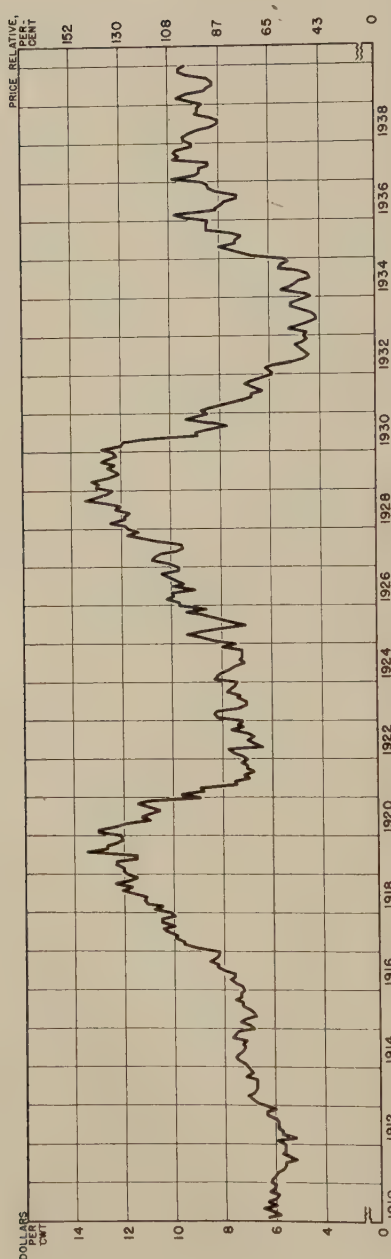


Figure 27. Veal calves. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Prices rose during the base period, 1921-29, to equal or exceed those which prevailed in 1918 and 1919. In 1932, 1933 and 1934, prices were lower than in prewar years but have made a sharp recovery since 1934. Changes in veal prices are similar to those for beef cattle. Veal calves usually are seasonally high in the spring and fall and low in the summer.

Table 58. Veal calves. Prices received by Kentucky producers on the 15th of the month, 1939 (dollars per 100 pounds).¹

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average ²
	6.40	5.80	6.20	6.60	6.00	6.40	6.00	5.90	6.30	6.10	6.00	6.20	6.16
	6.20	6.10	6.00	5.70	5.60	5.60	5.20	5.40	5.70	5.60	5.60	5.60	5.65
	5.90	5.20	5.70	5.70	5.90	5.90	5.90	6.00	6.40	6.40	6.00	6.50	5.94
	6.70	6.90	7.10	6.80	6.70	6.70	6.70	6.70	7.20	6.90	7.00	7.10	6.85
	7.20	7.50	7.60	7.50	7.30	7.20	7.30	7.20	7.80	7.60	7.50	6.80	7.38
	7.00	7.40	7.20	6.70	6.80	7.00	7.30	7.30	7.60	7.30	7.30	7.20	7.16
	7.30	7.60	7.80	7.60	7.60	8.00	8.30	8.30	8.60	8.30	8.20	8.20	8.00
	9.10	9.60	9.60	10.00	9.90	10.30	10.40	10.00	10.50	10.50	10.00	10.20	10.05
	10.80	10.40	11.10	11.20	11.10	11.60	12.10	11.60	12.40	11.70	11.50	11.90	11.49
	12.00	12.00	12.40	12.30	11.50	11.50	13.50	12.70	12.70	12.30	12.00	12.10	12.28
	13.00	13.00	12.30	11.90	10.90	11.30	10.90	10.70	11.10	11.50	11.00	8.90	11.35
	9.70	8.80	9.00	7.40	7.50	6.90	7.10	6.70	7.00	7.00	7.30	7.00	7.51
	7.20	7.60	7.80	6.40	6.70	7.00	6.70	7.00	7.70	7.20	7.40	7.20	7.10
	8.20	8.30	8.20	7.30	7.00	7.00	7.40	7.30	7.90	7.70	7.50	7.40	7.53
	8.30	8.20	8.00	7.80	7.50	7.10	7.30	7.20	7.20	7.20	8.00	7.50	7.54
	8.30	8.80	9.40	8.80	7.90	7.00	7.80	8.10	8.80	9.40	8.60	9.70	8.41
	9.70	10.30	9.90	10.00	9.10	9.90	9.50	9.90	10.10	10.40	9.70	9.70	9.82
	10.10	10.80	10.70	10.40	9.80	9.50	9.60	10.60	11.20	11.80	11.30	11.70	10.48
	11.80	12.50	11.80	11.80	11.60	12.30	12.00	12.60	13.50	12.90	12.60	12.40	12.28
	13.00	12.90	13.20	12.50	12.10	12.20	12.60	12.30	12.80	12.60	12.20	12.30	12.53
	12.80	12.00	11.90	11.00	8.90	9.00	8.50	7.70	8.60	9.50	9.00	8.50	9.60
	8.80	8.30	7.80	7.10	6.70	6.70	6.30	6.70	7.00	6.70	6.30	5.90	6.97
	6.00	6.20	5.90	5.10	4.60	4.40	4.60	4.80	5.00	4.75	4.55	4.65	4.98
	4.50	5.30	5.00	4.40	4.20	4.20	4.35	4.85	5.20	5.20	4.70	4.35	4.65
	4.65	5.50	5.20	5.00	4.85	4.35	4.40	4.85	5.60	5.50	5.30	5.40	4.98
	6.70	7.20	7.50	8.00	7.40	7.40	7.10	7.50	8.50	8.50	8.50	8.40	7.67
	9.30	9.80	8.10	8.10	7.90	7.80	7.30	7.30	8.10	8.40	8.40	8.70	8.11
	9.90	9.00	8.80	8.80	8.40	8.40	9.90	9.60	9.80	9.70	9.10	9.10	9.17
	9.40	9.40	9.20	8.90	8.30	8.00	8.00	8.30	9.00	8.90	8.90	8.70	8.65
	9.10	9.70	9.30	8.60	8.50	8.20	8.30	8.50	9.30	9.60	9.60	9.30	8.87

¹Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets", Bureau of Agricultural Economics, U. S. Department of Agriculture.
²For calendar year, weighted by average monthly marketings of 1926-1930.

Table 59. Veal calves. Relatives of prices received by Kentucky producers on the 15th of the month, 1910-1939 (average annual prices, 1921-1929 = 100).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. average
1	69	63	67	71	65	69	65	64	68	66	65	67	67
2	67	66	65	62	61	61	56	58	62	61	61	61	61
3	64	56	62	62	64	64	64	65	69	69	65	70	64
4	73	75	77	74	73	73	73	73	78	75	76	77	74
5	78	81	82	81	79	78	79	78	84	82	81	74	80
6	76	80	78	73	74	76	79	79	82	79	79	78	77
7	79	82	84	82	82	87	90	90	93	90	89	89	87
8	98	104	104	108	107	111	113	108	114	114	108	110	109
9	117	113	120	121	120	126	131	126	134	127	124	129	124
0	130	130	134	133	124	124	146	137	137	133	130	131	133
1	141	141	133	129	118	122	118	116	120	124	119	96	123
2	105	95	97	80	81	75	77	73	76	76	79	76	81
3	78	82	84	69	73	76	73	76	83	78	80	78	77
4	89	90	89	79	76	76	80	79	85	83	81	80	81
5	90	89	87	84	81	77	79	78	78	78	87	81	82
6	90	95	102	95	85	76	84	88	95	102	93	105	91
7	105	111	107	108	98	107	103	107	109	113	105	105	106
8	109	117	116	113	106	103	104	115	121	128	122	127	113
9	128	135	128	128	126	133	130	136	146	140	136	134	133
0	141	140	143	135	131	132	136	133	139	136	132	133	136
1	139	130	129	119	96	97	92	83	93	103	97	92	104
2	95	90	84	77	73	73	68	73	76	73	68	64	75
3	65	67	64	55	50	48	50	52	54	51	49	50	54
4	49	57	54	48	45	45	47	52	56	56	51	47	50
5	50	60	56	54	52	47	48	52	61	60	57	58	54
6	73	78	81	87	80	80	77	81	92	92	92	91	83
7	101	106	88	88	85	84	79	79	88	91	91	94	88
8	107	97	95	95	91	91	107	104	106	105	98	98	99
9	102	102	100	96	90	87	87	90	97	96	96	94	94
0	98	105	101	93	92	89	90	92	101	104	104	101	96

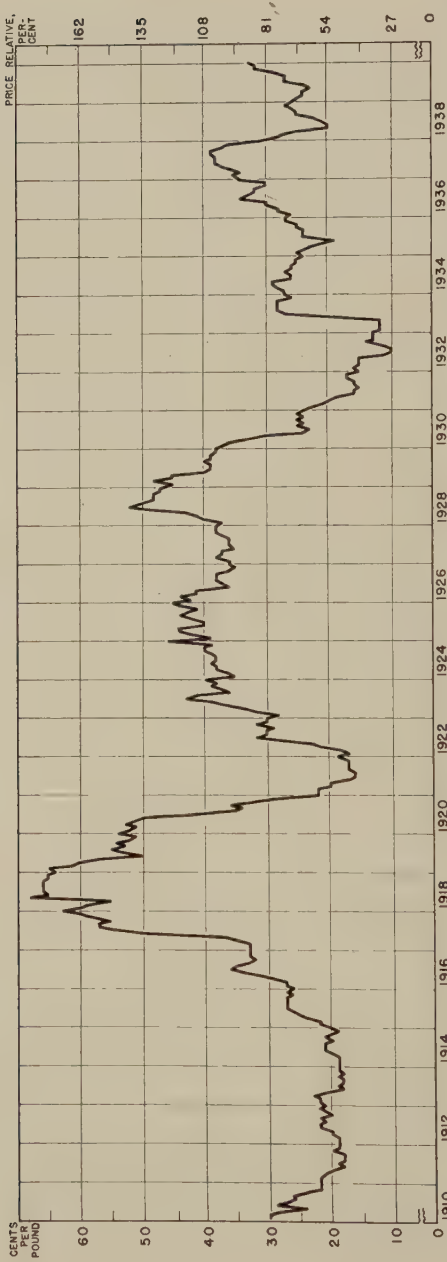


Figure 28. Wool. Prices received by Kentucky producers on the 15th of the month, 1910-1939, and corresponding relatives of prices. (For price relatives, annual average prices, 1921-1929 = 100.)

Wool prices are subject to violent changes when affected by war conditions or changes in international price relationships. Extremely sharp changes in price took place in 1917, 1920, and 1933.

Table 60. Wool. Prices received by Kentucky producers on the 15th of the month, 1910- (cents per pound).¹

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage ²
30	30	28	24	29	27	26	26	24	22	22	22	27
22	22	21	20	18	19	18	18	18	20	19	19	19
19	19	20	20	22	22	21	22	20	21	22	21	22
22	22	23	21	18	19	18	18	19	18	19	19	19
19	19	19	20	21	21	21	20	21	20	19	20	21
22	22	24	25	26	27	27	27	27	26	27	26	27
27	27	29	31	34	36	35	33	32	33	33	33	35
33	33	35	37	50	54	57	57	55	59	60	63	54
60	59	55	68	65	66	66	66	66	65	65	64	66
65	61	60	57	50	53	55	53	54	52	51	54	53
52	51	53	51	50	42	35	34	36	32	28	22	42
22	22	20	20	17	16	16	17	17	17	17	19	16
17	18	22	23	28	32	30	30	29	32	30	30	31
28	32	34	37	39	43	41	36	37	39	38	40	41
35	36	38	38	39	38	38	39	40	40	39	46	38
39	42	44	44	40	40	42	44	43	41	44	45	41
42	44	41	41	36	37	38	38	38	36	35	36	37
36	38	37	37	35	36	36	36	37	38	38	38	36
37	40	41	43	49	52	50	48	48	48	47	47	51
45	48	45	45	40	39	39	40	39	39	38	38	39
37	36	33	30	24	23	25	24	25	24	25	24	24
23	21	20	19	16	16	15	16	16	17	17	15	16
16	15	15	15	11	10	10	11	14	13	13	13	10
12	12	12	12	20	27	28	28	28	28	26	27	26
27	28	29	29	26	26	27	26	26	25	25	24	26
25	24	23	21	19	24	24	24	25	25	27	27	23
26	28	28	30	30	34	33	32	32	30	30	34	33
35	34	35	37	38	38	38	39	39	37	36	31	38
28	27	25	20	20	21	23	25	25	26	27	26	22
25	24	24	23	24	27	27	27	29	32	32	33	27

Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricul-
ral Economics, U. S. Department of Agriculture.
For calendar year, weighted by average monthly marketings of 1926-1930.

Table 61. Wool. Relatives of prices received by Kentucky producers on the 15th of the
h, 1910-1939 (average annual prices, 1921-1929 = 100).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. av- erage
81	81	76	65	78	73	70	70	65	59	59	59	73
59	59	57	54	49	51	49	49	49	54	51	51	51
51	51	54	54	59	59	57	59	54	57	59	57	59
59	59	62	57	49	51	49	49	51	49	51	51	51
51	51	51	54	57	57	57	54	57	54	51	54	57
59	59	65	68	70	73	73	73	73	70	73	70	73
73	73	78	84	92	97	95	89	86	89	89	89	95
89	89	95	100	135	146	154	154	149	159	162	170	146
162	159	149	184	176	178	178	178	178	176	176	173	178
176	165	162	154	135	143	149	143	146	141	138	146	143
141	138	143	138	135	114	95	92	97	86	76	59	113
59	59	54	54	46	43	43	46	46	46	46	51	43
46	49	59	62	76	86	81	81	78	86	81	81	84
76	86	92	100	105	116	111	97	100	105	103	108	111
95	97	103	103	105	103	103	105	108	108	105	124	103
105	114	119	119	108	108	114	119	116	111	119	122	111
114	119	111	111	97	100	103	103	103	97	95	97	100
97	103	100	100	95	97	97	97	100	103	103	103	97
100	108	111	116	132	141	135	130	130	130	127	127	138
122	130	122	122	108	105	105	108	105	105	103	103	105
100	97	89	81	65	62	68	65	68	65	68	65	65
62	57	54	51	43	43	41	43	43	46	46	41	43
43	41	41	41	30	27	27	30	38	35	35	35	27
32	32	32	32	54	73	76	76	76	76	70	73	70
73	76	78	78	70	70	73	70	70	68	68	65	70
68	65	62	57	51	65	65	65	68	68	73	73	62
70	76	76	81	81	92	89	86	86	81	81	92	89
95	92	95	100	103	103	103	105	105	100	97	84	103
76	73	68	54	54	57	62	68	68	70	73	70	59
68	65	65	62	65	73	73	73	78	86	86	89	73

MINOR LIVESTOCK AND LIVESTOCK PRODUCTS

Table 62. Butter. Prices received by Kentucky producers on the 15th of the month, 1939 (cents per pound).¹

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. er
1910	23	22	22	22	21	20	19	20	20	20	22	22	
1911	21	20	20	20	18	18	18	18	18	19	21	22	
1912	22	22	21	21	21	20	19	18	19	20	22	23	
1913	22	22	22	22	22	21	21	21	22	22	22	23	
1914	23	22	22	22	20	20	20	20	21	21	22	22	
1915	22	22	22	22	20	18	18	19	20	21	22	22	
1916	22	22	22	22	22	21	21	22	22	24	26	26	
1917	26	28	28	28	28	27	27	28	30	32	32	34	
1918	36	36	35	33	32	31	31	33	35	36	39	40	
1919	40	38	37	39	40	39	38	38	40	42	46	49	
1920	48	47	46	46	44	42	41	40	43	46	46	42	
1921	36	34	33	31	28	26	26	28	30	32	32	32	
1922	30	28	28	28	28	28	28	26	28	30	32	34	
1923	34	33	34	34	32	31	32	32	32	34	36	37	
1924	38	38	37	35	33	32	31	34	34	34	37	34	
1925	38	35	33	36	38	31	33	33	34	36	35	37	
1926	38	34	34	35	34	34	34	33	34	35	37	38	
1927	36	34	35	36	35	34	36	33	36	36	37	38	
1928	38	36	37	37	36	36	35	37	39	37	39	39	
1929	38	38	38	37	37	37	36	36	37	39	39	37	
1930	35	34	34	35	34	32	31	30	35	35	34	31	
1931	30	26	27	28	25	24	24	25	25	28	27	27	
1932	24	21	22	21	18	18	16	19	18	19	19	21	
1933	20	19	17	19	18	18	20	19	20	20	21	19	
1934	19	19	23	21	20	20	20	21	21	21	23	23	
1935	25	26	25	25	24	23	22	22	24	24	25	26	
1936	27	27	25	25	25	25	26	28	28	27	28	27	
1937	27	27	28	27	27	27	27	27	28	28	28	29	
1938	27	26	26	25	25	24	23	23	25	25	25	25	
1939	24	24	22	22	22	22	23	22	23	23	24	24	

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² For calendar year, weighted by average monthly marketings of butterfat, 1930-1932.

Table 63. Turkeys. Prices received by Kentucky producers on the 15th of the month, 1913-1939 (cents per pound).¹

Year	Jan.	Feb.	Mar.	Apr.	Aug.	Sept.	Oct.	Nov.	Dec.	Wtd. er
1913	13.8	.....	.....	.....	.....	.....	13.7	13.7	14.0	
1914	13.7	.....	.....	.....	.....	.....	13.0	12.1	12.1	
1915	12.3	.....	.....	.....	.....	.....	12.1	14.0	14.5	
1916	14.4	.....	.....	.....	.....	.....	16.1	17.7	19.0	
1917	18.7	.....	.....	.....	.....	.....	17.8	20.5	21.3	
1918	21.2	.....	.....	.....	.....	.....	21.0	23.6	23.6	
1919	24.0	.....	.....	.....	.....	.....	24.0	28.0	30.0	
1920	30.4	.....	.....	.....	.....	.....	31.0	33.0	34.0	
1921	32.0	.....	.....	.....	.....	.....	25.0	26.0	32.0	
1922	30.0	.....	.....	.....	.....	.....	26.0	31.0	32.0	
1923	27.3	.....	.....	.....	.....	.....	26.0	27.8	22.0	
1924	21.0	.....	.....	.....	.....	.....	.....	24.7	22.0	
1925	24.9	.....	.....	.....	.....	.....	22.6	27.1	28.0	
1926	29.3	.....	.....	.....	.....	.....	26.8	27.0	29.0	
1927	29.0	.....	.....	.....	.....	.....	25.0	31.0	31.0	
1928	28.0	.....	.....	.....	.....	.....	26.0	30.0	30.0	
1929	28.0	.....	.....	.....	.....	.....	26.0	26.0	20.0	
1930	22.0	.....	.....	.....	.....	.....	20.0	18.0	17.0	
1931	20.0	.....	.....	.....	.....	.....	16.0	16.0	18.0	
1932	17.0	.....	.....	.....	.....	.....	13.0	13.0	11.0	
1933	9.0	9.0	9.0	12.0	.....	.....	10.0	10.0	10.0	
1934	11.0	12.0	13.0	9.8	.....	.....	12.0	14.0	15.0	
1935	15.0	15.0	15.0	.....	.....	.....	15.0	19.0	20.0	
1936	19.0	19.0	.....	.....	.....	14.0	15.0	15.0	14.0	
1937	14.0	14.0	.....	.....	.....	14.0	15.0	17.0	18.0	
1938	18.0	.....	.....	.....	.....	13.0	13.0	15.0	16.0	
1939	18.0	16.0	.....	.....	.....	13.0	14.0	14.0	16.0	

¹ Monthly prices from Statistical Bulletin No. 16 and "Crops and Markets," Bureau of Agricultural Economics, U. S. Department of Agriculture.

² Based upon estimated marketings of January, 10% ; October, 5% ; November, 4% ; December, 40%.

Table 64. Annual average prices, 1921-1929, for livestock, livestock products, crops (other than tobacco) and crop-year average prices of tobacco, 1920-1929, Kentucky.

Commodity	Average price
Major crops	
Apples	138 cents per bushel
Barley	83 cents per bushel
Corn	93 cents per bushel
Hay (all, loose)	16.30 dollars per ton
Oats	62 cents per bushel
Potatoes	141 cents per bushel
Rye	114 cents per bushel
Strawberries	3.63 dollars per 24-quart crate
Sweetpotatoes	144 cents per bushel
Tobacco, type 22 (Eastern fire-cured)	11.89 cents per pound
type 23 (Western fire-cured)	9.29 cents per pound
type 24 (Henderson fire-cured)	10.45 cents per pound
type 31 (Burley)	21.71 cents per pound
type 35 (One Sucker)	10.14 cents per pound
type 36 (Green River)	10.68 cents per pound
Wheat	133 cents per bushel
Major livestock and livestock products	
Beef cattle	6.61 dollars per 100 pounds
Butterfat	40.3 cents per pound
Chickens	20 cents per pound
Eggs	25 cents per dozen
Hogs	9.34 dollars per 100 pounds
Horses	64 dollars per head
Lambs	11.45 dollars per 100 pounds
Milk cows	51 dollars per head
Mules	82 dollars per head
Sheep	5.47 dollars per 100 pounds
Veal calves	9.24 dollars per 100 pounds
Wool	37 cents per pound

PRODUCTION, PRICE AND FARM VALUE OF CROPS IN KENTUCKY

Frequently there is need for information relative to the acreage of various crops as well as to the volume and value of yearly crop production in Kentucky. Tables 65 to 104 present such information for the more important crops grown in this State.

The acreage, yield per acre, and production figures are those prepared by the Division of Crop and Livestock Estimates of the United States Department of Agriculture. When available, average prices received by growers during the crop marketing season and total farm value are taken from the same source. In other cases, however, average annual prices have been calculated from monthly prices and monthly marketings. This is particularly true for the years prior to 1931. Monthly marketings in all years are not available so for the grains and hay, average monthly sales during the crop years from 1925-26 to 1929-30 are used to weight monthly prices each year. For other crops, and for livestock items, average sales by months for the calendar years 1926 to 1930 are used.

Farm value in each case is obtained by applying the weighted average price per unit to the total quantity produced. It should not be interpreted as income because only a portion of the quantity produced is sold. The proportion sold varies between crops (for grains, see table 86). Production listed as "commercial" is grown essentially for market, as is the case with tobacco, but such crops as corn and hay are used extensively on the farms where grown.

Data on most of the commodities may be obtained in future years from December issues of "Crops and Markets," annual issues of "Agricultural Statistics," and "General Crop Reports" all of which are published by the U. S. Department of Agriculture.

FRUITS AND VEGETABLES

Table 65. Apples. Production, price per bushel, and estimated farm value, Kentucky, 1919-1938.

Year	Production	Price per bushel ²	Estimated farm value
	(bushels)	(dollars)	(dollars)
1919	1,281,000	2.28	2,921,090
1920	4,284,000	1.48	6,340,000
1921	630,000	2.15	1,354,000
1922	4,788,000	1.23	5,889,000
1923	2,205,000	1.46	3,219,000
1924	5,132,000	1.02	5,235,000
1925	2,065,000	1.41	2,912,000
1926	4,984,000 ¹	.85	4,109,000 ¹
1927	530,000	1.79	949,000
1928	4,080,000	1.00	4,080,000
1929	1,384,000	1.47	2,034,000
1930	833,000	1.35	1,125,000
1931	4,802,000	.50	2,401,000
1932	784,000	.81	635,000
1933	2,522,000	.87	2,194,000
1934	1,011,000	.97	981,000
1935	1,615,000	.85	1,373,000
1936	598,000	1.14	682,000
1937	3,870,000	.92	3,560,000
1938 ³	801,000	1.00	801,000

Data from "Revised Production Estimates of Fruits and Nuts" (mimeo. March, 1938), and statistical sections of the "Yearbook of Agriculture," publications of the U. S. Department of Agriculture. Farm value is calculated.

¹ Includes an estimate of 150,000 bushels not harvested on account of market conditions. No value was assigned to this production.

² Weighted average price for crop marketing season beginning June 1; 1919-1930 prices are calculated from the 15th of month prices and weighted by average monthly marketings of 1926-1930; others are season average prices published by U. S. Department of Agriculture.

³ Preliminary.

Table 66. Cabbage (for market and for kraut). Commercial acreage, yield per acre, production, price per ton and farm value, Kentucky, 1918-1939.

Marketing season	Acreage	Yield per acre	Production	Price per ton ¹	Farm value
	(acres)	(tons)	(tons)	(dollars)	(dollars)
1918	200	9.2	1,800	17.20	31,000
1919	350	8.6	3,000	22.00	66,000
1920	350	6.6	2,300	24.40	56,000
1921	360	7.2	2,600	20.00	52,000
1922	300	6.0	1,800	19.40	35,000
1923	300	5.0	1,500	30.00	45,000
1924	360	6.5	2,300	25.00	58,000
1925	240	7.0	1,700	45.00	76,000
1926	240	7.0	1,700	20.00	34,000
1927	240	6.8	1,600	36.30	58,000
1928	260	6.3	1,600	15.00	24,000
1929	200	10.2	2,000	30.00	60,000
1930	190	4.5	900	34.00	31,000
1931	270	7.0	1,900	20.00	38,000
1932	270	5.0	1,400	35.00	49,000
1933	300	5.0	1,500	30.00	45,000
1934	300	5.5	1,600	22.00	35,000
1935	320	6.4	2,000	13.00	26,000
1936	250	2.7	700	45.00	32,000
1937	300	6.5	2,000	18.00	36,000
1938	300	7.0	2,100	15.00	32,000
1939 ²	250	4.5	1,100	18.00	20,000

Data from "Commercial Truck Crops for Shipment, Cabbage (for market and for Kraut), 1918-1927 and 1928-1936" (mimeo. February 1937 and December 1936), statistical sections of "Yearbook of Agriculture," and "Truck and Canning Crop Report," (December 1939), publications of the U. S. Department of Agriculture.

¹ Average price received by growers for crop marketing season.

² Preliminary.

Table 67. Early Irish potatoes (for market). Commercial acreage, yield per acre, production, price per bushel and farm value, Kentucky, 1918-1939.

Marketing season	Acreage	Yield per acre	Production	Price per bushel ¹	Farm value
	(acres)	(bushels)	(bushels)	(dollars)	(dollars)
1918	4,500	89	400,000	1.20	480,000
1919	5,700	94	536,000	1.45	777,000
1920	5,700	103	587,000	2.07	1,215,000
1921	5,100	75	382,000	1.00	382,000
1922	5,500	101	556,000	1.22	678,000
1923	5,700	111	633,000	1.47	931,000
1924	5,900	149	879,000	.79	694,000
1925	5,600	106	594,000	1.63	968,000
1926	5,600	105	588,000	1.25	735,000
1927	5,300	125	662,000	.94	622,000
1928	5,300	130	689,000	.38	262,000
1929	4,300	168	722,000	1.35	975,000
1930	5,300	74	392,000	.90	353,000
1931	5,200	90	468,000	.59	276,000
1932	5,000	105	525,000	.35	184,000
1933	5,500	96	528,000	1.30	686,000
1934	6,500	50	325,000	.50	162,000
1935	6,000	88	528,000	.50	264,000
1936	5,000	40	200,000	1.25	250,000
1937	3,000	110	330,000	.65	214,000
1938	2,700	165	446,000	.65	290,000
1939 ²	3,100	153	474,000	.80	379,000

Data from "Commercial Truck Crops for Shipment, Early Commercial Irish Potatoes (for market), 1918-1927, 1928-1937 and 1939" (mimeo. March 1938, February and August 1939), statistical sections of the "Yearbook of Agriculture," and "Truck and Canning Crop Report (December, 1939)," publications of the U. S. Department of Agriculture.

¹ Average price received by growers for crop marketing season.

² Preliminary.

Table 68. Grapes. Production, 1919-1939, price per ton, and farm value, Kentucky, 1930-1939.

Year	Production	Price per ton ¹	Farm value
	(tons)	(dollars)	(dollars)
1919	750		
1920	1,020		
1921	550		
1922	1,050		
1923	870		
1924	1,100		
1925	990		
1926	1,270		
1927	610		
1928	1,080		
1929	830		
1930	810	65.00	53,000
1931	1,550	55.00	85,000
1932	1,450	40.00	58,000
1933	2,000	45.00	90,000
1934	2,440	50.00	122,000
1935	1,920	65.00	125,000
1936	2,200	60.00	132,000
1937	2,960	60.00	178,000
1938 ²	2,390	60.00	143,000
1939 ²	2,750		

Data from "Revised Production Estimates of Fruits and Nuts" (mimeo. March 1938), "General Crop Report" (December 1939), and statistical sections of the "Yearbook of Agriculture," publications of the U. S. Department of Agriculture.

¹ Average price received by growers for crop marketing season.

² Preliminary.

Table 69. Onions (for market). Commercial acreage, yield per acre, production, price per 100 pounds and farm value, Kentucky, 1918-1939.

Marketing season	Acreage	Yield per acre	Production	Price per 100 lbs. ²	Farm value
	(acres)	(sacks) ¹	(sacks) ¹	(dollars)	(dollars)
1918	850	172	146,000	3.05	445,000
1919	1,000	171	171,000	3.60	616,000
1920	900	211	190,000	1.84	350,000
1921	1,000	171	171,000	1.23	210,000
1922	1,000	128	128,000	2.23	285,000
1923	1,000	170	170,000	2.49	423,000
1924	1,100	171	188,000	2.19	412,000
1925	750	160	120,000	2.77	332,000
1926	1,000	142	142,000	.88	125,000
1927	800	79	63,000	1.75	110,000
1928	800	220	176,000	.80	141,000
1929	600	45	27,000	1.85	50,000
1930	510	20	10,000	1.30	13,000
1931	400	210	84,000	1.25	105,000
1932	400	125	50,000	.70	35,000
1933	340	105	36,000	1.50	54,000
1934	350	85	30,000	1.35	40,000
1935	350	120	42,000	1.41	59,000
1936	350	70	24,000	1.15	28,000
1937	150	150	22,000	1.50	33,000
1938	160	160	26,000	1.50	39,000
1939 ³	170	160	17,000	1.00	17,000

Data from publications of the Bureau of Agricultural Economics, U. S. Department of Agriculture.

¹ Sacks containing 100 pounds.

² Average price received by growers for crop marketing season.

³ Preliminary.

Table 70. Peaches. Production, price per bushel, and farm value, Kentucky, 1919-1939.

Year	Production	Price per bushel ¹	Farm value
	(bushels)	(dollars)	(dollars)
1919	472,000	2.40	1,133,000
1920	1,030,000	2.25	2,318,000
1921	93,000	3.00	279,000
1922	1,144,000	1.40	1,602,000
1923	418,000	1.64	686,000
1924	1,130,000	1.45	1,638,000
1925	522,000	1.75	914,000
1926	1,006,000	1.30	1,308,000
1927	162,000	1.90	308,000
1928	911,000	1.25	1,139,000
1929	530,000	1.45	768,000
1930	65,000	1.70	110,000
1931	1,280,000	.55	704,000
1932	84,000	1.15	97,000
1933	237,000	1.05	249,000
1934	490,000	1.00	490,000
1935	632,000	.90	569,000
1936	131,000	1.40	183,000
1937	1,369,000	.90	1,232,000
1938 ²	352,000	1.15	405,000
1939 ²	562,000		

Data from "Revised Production Estimates of Fruits and Nuts" (mimeo. March, 1938), "Monthly Crop Reporter," "Crops and Markets," "General Crop Report" (December, 1939), and statistical sections of the "Yearbook of Agriculture," publications of the U. S. Department of Agriculture. Farm value is calculated.

¹ For 1919-1925, September 15 prices; other prices are average prices received by growers for crop marketing season.

² Preliminary.

Table 71. Pears. Production, price per bushel and farm value, Kentucky, 1919-1939.

Year	Production	Price per bushel ¹	Farm value
	(bushels)	(dollars)	(dollars)
1919	55,000	1.80	99,000
1920	131,000	1.95	255,000
1921	13,000	2.33	30,000
1922	150,000	1.55	232,000
1923	88,000	1.32	116,000
1924	166,000	1.42	236,000
1925	130,000	1.35	176,000
1926	238,000	.95	226,000
1927	60,000	1.45	87,000
1928	221,000	1.10	243,000
1929	256,000	1.00	256,000
1930	62,000	1.35	84,000
1931	382,000	.50	191,000
1932	50,000	.90	45,000
1933	110,000	.80	88,000
1934	275,000	.65	179,000
1935	192,000	.80	154,000
1936	80,000	1.00	80,000
1937	411,000	.65	267,000
1938 ²	135,000	.80	108,000
1939 ²	206,000		

Data from "Revised Production Estimates of Fruits and Nuts" (mimeo. March, 1938), "Monthly Crop Reporter," "Crops and Markets," "General Crop Report" (December, 1939), and statistical sections of "Yearbook of Agriculture," publications of the U. S. Department of Agriculture. Farm value is calculated.

¹ For 1919-1925, November 15 prices; other prices are average prices received by growers for crop marketing season.

Table 72. Potatoes. Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ²	Estimated farm value
	(acres)	(bushels) ¹	(bushels) ¹	(cents)	(dollars)
1909	56,000	92	5,152,000	72	3,709,000
1910	57,000	91	5,187,000	59	3,060,000
1911	52,000	39	2,028,000	147	2,981,000
1912	50,000	97	4,850,000	83	4,026,000
1913	48,000	49	2,352,000	89	2,093,000
1914	48,000	40	1,920,000	113	2,170,000
1915	49,000	107	5,243,000	59	3,093,000
1916	46,000	81	3,726,000	92	3,428,000
1917	58,000	88	5,104,000	167	8,524,000
1918	55,000	70	3,850,000	156	6,006,000
1919	53,000	65	3,445,000	207	7,131,000
1920	51,000	88	4,488,000	267	11,983,000
1921	49,000	55	2,695,000	157	4,231,000
1922	48,000	80	3,840,000	139	5,338,000
1923	47,000	86	4,020,000	139	5,588,000
1924	45,000	95	4,275,000	122	5,216,000
1925	44,000	68	2,992,000	180	5,386,000
1926	45,000	89	4,005,000	160	6,408,000
1927	50,000	90	4,500,000	170	7,650,000
1928	56,000	106	5,936,000	97	5,758,000
1929	49,000	95	4,655,000	110	5,120,000
1930	44,000	63	2,772,000	136	3,770,000
1931	52,000	72	3,744,000	76	2,845,000
1932	51,000	77	3,927,900	64	2,513,000
1933	49,000	66	3,234,000	103	3,331,000
1934	49,000	70	3,430,900	80	2,744,000
1935	52,000	86	4,472,000	72	3,220,000
1936	47,000	36	1,692,000	132	2,233,000
1937	47,000	93	4,371,000	76	3,322,000
1938 ³	45,000	103	4,635,000	70	3,244,000
1939 ³	46,000	84	3,864,000		

Data from "Revised Estimates of Potato Acreage, Yield per Acre and Production, 1866-1929" (mimeo. August, 1935), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1935), statistical sections of the "Yearbook of Agriculture," and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ Bushels of approximately 60 pounds.

² Weighted average price for crop year beginning July 1, 1909-1930, calculated from 15th of month prices and weighted by average monthly marketings of 1926-1930; others are season average prices as published by U. S. Department of Agriculture.

³ Preliminary.

Table 73. Strawberries (for market). Commercial acreage, yield per acre, production, price per 24-quart crate and farm value, Kentucky, 1918-1939.

Marketing season	Acreage	Yield per acre	Production	Price per 24-quart crate ¹	Farm value
	(acres)	(crates)	(crates)	(dollars)	(dollars)
1918	4,060	76	309,000	4.10	1,267,000
1919	3,800	45	171,000	5.00	855,000
1920	3,440	65	224,000	4.40	986,000
1921	4,200	75	315,000	4.80	1,512,000
1922	4,520	85	384,000	3.60	1,382,000
1923	5,080	81	411,000	3.35	1,377,000
1924	4,400	59	260,000	3.60	936,000
1925	3,900	46	179,000	4.55	814,000
1926	4,400	66	290,000	3.60	1,044,000
1927	8,000	56	448,000	3.85	1,725,000
1928	8,200	60	492,000	2.40	1,181,000
1929	5,400	71	383,000	2.60	996,000
1930	4,000	51	204,000	4.30	877,000
1931	3,300	55	182,000	3.75	682,000
1932	5,400	88	475,000	1.90	902,000
1933	10,000	54	540,000	1.20	648,000
1934	9,300	50	465,000	1.65	767,000
1935	8,200	59	484,000	2.30	1,113,000
1936	8,200	23	189,000	3.05	576,000
1937	6,700	41	275,000	3.00	825,000
1938	7,700	55	424,000	2.15	912,000
1939 ²	8,900	60	534,000	1.95	1,041,000

Data from "Commercial Truck Crops for Shipment, Strawberries (for market, Cold Pack, etc.), 1918-1927 and 1928-1936" (mimeo. October, 1937 and December, 1936), statistical sections of "Yearbook of Agriculture," and "Truck and Canning Crop Report" (December), publications of U. S. Department of Agriculture.

¹ Average price received by growers for crop marketing season as calculated by U. S. Department of Agriculture. These prices differ somewhat from those received by members of strawberry marketing associations.

² Preliminary.

Table 74. Sweetpotatoes. Acreage, yield, production, season farm price and value, Kentucky, 1910-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1910	11,000	98	1,078,000	87	938,000
1911	10,000	99	990,000	100	990,000
1912	9,000	108	972,000	92	894,000
1913	9,000	76	684,000	102	698,000
1914	10,000	101	1,010,000	93	939,000
1915	10,000	105	1,050,000	84	882,000
1916	10,000	92	920,000	112	1,030,000
1917	12,000	100	1,200,000	142	1,704,000
1918	12,000	90	1,080,000	180	1,944,000
1919	15,000	85	1,275,000	208	2,652,000
1920	14,000	95	1,330,000	177	2,354,000
1921	14,000	90	1,260,000	139	1,751,000
1922	14,000	105	1,470,000	127	1,867,000
1923	13,000	95	1,235,000	151	1,865,000
1924	12,000	75	900,000	153	1,377,000
1925	14,000	80	1,120,000	181	2,027,000
1926	17,000	105	1,785,000	124	2,213,000
1927	16,000	85	1,360,000	139	1,890,000
1928	14,000	80	1,120,000	134	1,501,000
1929	14,000	91	1,274,000	134	1,707,000
1930	13,000	65	845,000	137	1,158,000
1931	23,000	96	2,208,000	80	1,766,000
1932	26,000	86	2,236,000	62	1,386,000
1933	23,000	88	2,024,000	79	1,599,000
1934	22,000	90	1,980,000	73	1,445,000
1935	25,000	80	2,000,000	78	1,560,000
1936	22,000	61	1,342,000	113	1,516,000
1937	24,000	90	2,160,000	83	1,793,000
1938 ²	24,000	95	2,280,000	75	1,710,000
1939 ²	24,000	82	1,968,000		

Data from "Revised Estimates of Sweet Potato Acreage, Yield per Acre and Production, 1868-1923" (mimeo. February, 1937), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1935), statistical sections of the "Yearbook of Agriculture," and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ For crop year, weighted average price for season; 1910-1930, weighted by average monthly marketings of 1926-1930; 1931-1938 as calculated by U. S. Department of Agriculture weighted by monthly marketings of each year.

² Preliminary.

Table 75. Tomatoes (for manufacture). Commercial acreage, yield per acre, price per ton and farm value, Kentucky, 1918-1938.

Marketing season	Acreage	Yield per acre	Production	Price per ton ¹	Farm value
	(acres)	(tons)	(tons)	(dollars)	(dollars)
1918	10,190	3.0	30,600	14.20	435,000
1919	2,560	5.5	14,100	15.59	220,000
1920	5,960	4.1	24,400	13.26	324,000
1921	2,580	3.3	8,500	10.00	85,000
1922	5,290	3.8	20,100	11.00	221,000
1923	3,500	2.0	7,000	11.52	81,000
1924	6,200	4.0	24,800	13.48	334,000
1925	9,550	4.0	38,200	13.46	514,000
1926	6,950	3.0	20,800	12.25	255,000
1927	6,530	3.2	20,900	13.08	273,000
1928	5,500	2.1	11,600	12.60	146,000
1929	6,400	3.7	23,700	12.60	299,000
1930	8,430	2.6	21,900	12.70	278,000
1931	5,700	2.8	16,000	10.40	166,000
1932	4,500	1.8	8,100	7.00	57,000
1933	4,000	2.0	8,000	9.50	76,000
1934	5,200	1.8	9,400	10.00	94,000
1935	7,900	2.0	15,800	10.00	158,000
1936	3,800	1.5	5,700	9.80	56,000
1937	3,900	3.7	14,400	11.80	170,000
1938	3,700	3.1	11,500	10.30	118,000
1939 ²	2,700	2.4	6,500	10.40	68,000

Data from "Commercial Truck Crops for Manufacture, Tomatoes (Manufacture), 1918-1928 and 1928-1936" (mimeo, October, 1934 and December, 1936), statistical sections of "Yearbook of Agriculture," "Truck and Canning Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ Average price received by growers for crop marketing season.

² Preliminary.

Table 76. Tomatoes (for market). Commercial acreage, yield per acre, production, price per bushel and farm value, Kentucky, 1918-1939.

Marketing season	Acreage	Yield per acre	Production	Price per bushel ¹	Farm value
	(acres)	(bushels)	(bushels)	(dollars)	(dollars)
1918	1,850	107	198,000	1.55	307,000
1919	1,850	140	259,000	1.50	388,000
1920	2,000	150	300,000	1.40	420,000
1921	1,700	125	212,000	1.70	360,000
1922	1,200	143	172,000	1.95	335,000
1923	1,600	143	229,000	1.50	344,000
1924	2,000	180	360,000	1.10	396,000
1925	1,900	143	272,000	1.35	367,000
1926	1,400	111	155,000	1.40	217,000
1927	1,630	114	186,000	1.20	223,000
1928	1,710	76	130,000	.80	104,000
1929	1,620	138	224,000	.90	202,000
1930	1,700	55	94,000	1.55	146,000
1931	2,100	90	189,000	1.05	198,000
1932	2,270	110	250,000	.40	100,000
1933	2,150	115	247,000	.55	136,000
1934	2,200	60	132,000	1.10	145,000
1935	1,500	100	150,000	.80	120,000
1936	2,500	65	162,000	1.00	162,000
1937	2,300	120	276,000	.65	179,000
1938	2,300	85	196,000	.40	78,000
1939 ²	2,300	90	207,000	.65	135,000

Data from "Commercial Truck Crops for Shipment, Tomatoes (for market), 1918-1927 and 1928-1936" (mimeo, May, 1937 and December, 1918), statistical sections of "Yearbook of Agriculture," and "Truck and Canning Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

² Preliminary.

GRAINS

Table 77. Barley. Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1909	3,000	24.0	72,000	70	50,000
1910	3,000	22.0	66,000	64	42,000
1911	3,000	21.5	64,000	72	46,000
1912	3,000	26.0	78,000	82	64,000
1913	3,000	23.5	70,000	73	51,000
1914	5,000	25.0	125,000	75	94,000
1915	6,000	24.5	147,000	67	98,000
1916	6,000	22.0	132,000	81	107,000
1917	5,000	23.0	115,000	135	155,000
1918	6,000	23.5	141,000	136	192,000
1919	6,000	21.5	129,000	155	200,000
1920	5,000	22.5	112,000	149	167,000
1921	6,000	21.0	126,000	64	81,000
1922	6,000	23.5	141,000	76	107,000
1923	7,000	22.5	158,000	78	123,000
1924	5,000	20.0	100,000	96	96,000
1925	6,000	22.0	132,000	93	123,000
1926	7,000	24.0	168,000	73	123,000
1927	6,000	22.5	135,000	86	116,000
1928	2,000	20.5	41,000	83	34,000
1929	5,000	23.5	118,000	97	114,000
1930	7,000	20.0	140,000	65	91,000
1931	13,000	28.0	364,000	39	142,000
1932	11,000	20.0	220,000	38	84,000
1933	16,000	23.0	368,000	58	213,000
1934	13,000	19.0	247,000	68	168,000
1935	17,000	21.0	357,000	54	193,000
1936	22,000	20.0	440,000	86	378,000
1937	35,000	26.0	910,000	75	682,000
1938 ²	39,000	24.0	936,000	53	496,000
1939 ²	51,000	22.0	1,122,000		

Data from "Revised Estimates of Barley Acreage, Yield and Production, 1866-1929" (mimeo. February, 1935), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June 1936), statistical sections of the "Yearbook of Agriculture" and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ Weighted average price for crop year beginning July 1; 1909-1930 prices are calculated from 15th of month prices and weighted by average monthly marketings of crop years 1925-1929, others are season average prices as published by the U. S. Department of Agriculture.

² Preliminary.

Table 78. Buckwheat. Acreage, yield per acre, production, price per bushel and farm value, Kentucky, 1919-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1919	8,000	10.0	80,000	100	80,000
1920	7,000	11.0	77,000	100	77,000
1921	7,000	10.5	74,000	100	74,000
1922	7,000	9.5	66,000	90	59,000
1923	7,000	10.5	74,000	100	74,000
1924	7,000	13.0	91,000	119	108,000
1925	5,000	7.5	38,000	100	38,000
1926	4,000	10.5	42,000	84	35,000
1927	3,000	9.5	28,000	86	24,000
1928	3,000	10.0	30,000	86	26,000
1929	2,000	10.5	21,000	102	21,000
1930	2,000	7.0	14,000	90	13,000
1931	2,000	11.0	22,000	50	11,000
1932	2,000	10.0	20,000	56	11,000
1933	2,000	8.0	16,000	80	13,000
1934	2,000	10.0	20,000	82	16,000
1935	2,000	13.0	26,000	87	23,000
1936	2,000	7.0	14,000	92	13,000
1937	2,000	11.0	22,000	78	17,000
1938 ²	2,000	13.5	27,000	72	19,000
1939 ²	2,000	8.0	16,000		

Data from "Revised Estimates of Buckwheat Acreage, Yield per Acre and Production, 1866-1929" (mimeo. August 1936), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June 1936), statistical sections of the "Yearbook of Agriculture" and "General Crop Report" (December 1939), publications of the U. S. Department of Agriculture.

¹ Prices 1919-1931 are December 1 prices, remaining are season average prices received by farmers for year beginning September 1.

² Preliminary.

Table 79. All corn.¹ Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ²	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1909	3,472,000	24.3	84,370,000	70	59,059,000
1910	3,470,000	25.5	88,485,000	60	53,091,000
1911	3,500,000	23.0	80,500,000	78	62,790,000
1912	3,500,000	27.0	94,500,000	65	61,425,000
1913	3,540,000	18.5	65,490,000	82	53,702,000
1914	3,540,000	23.0	81,420,000	75	61,065,000
1915	3,650,000	27.5	100,375,000	72	72,270,000
1916	3,540,000	26.0	92,040,000	126	115,970,000
1917	3,850,000	29.0	111,650,000	153	170,824,000
1918	3,680,000	23.5	86,480,000	172	148,746,000
1919	3,540,000	22.5	79,650,000	179	142,574,000
1920	3,356,000	27.5	92,290,000	82	75,678,000
1921	3,178,000	22.0	69,916,000	70	48,941,000
1922	3,060,000	24.0	73,440,000	87	63,893,000
1923	3,156,000	24.0	75,744,000	98	74,229,000
1924	3,048,000	23.0	70,104,000	112	78,516,000
1925	3,231,000	23.0	74,313,000	85	63,166,000
1926	3,069,000	27.5	84,398,000	78	65,830,000
1927	2,885,000	23.0	66,355,000	111	73,654,000
1928	3,029,000	20.0	60,580,000	109	66,032,000
1929	2,843,000	23.1	65,673,000	95	62,389,000
1930	2,871,000	10.0	28,710,000	85	24,404,000
1931	2,986,000	27.0	80,622,000	34	27,411,000
1932	2,866,000	23.0	65,918,000	39	25,708,000
1933	2,866,000	24.5	70,217,000	58	40,726,000
1934	2,858,000	22.0	62,876,000	81	50,930,000
1935	2,829,000	22.0	62,238,000	85	52,902,000
1936	3,027,000	18.0	54,486,000	111	60,479,000
1937	2,906,000	26.0	75,556,000	58	43,822,000
1938 ³	2,761,000	27.0	74,547,000	53	39,510,000
1939 ⁴	2,816,000	25.0	70,400,000		

Data from information direct from the U. S. Department of Agriculture in addition to "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June 1936), statistical sections of "Yearbook of Agriculture" and "General Crop Report" (December 1939), publications of the U. S. Department of Agriculture. Farm value is calculated.

¹ Corn for all purposes, including hogged and siloed corn, and that cut and fed without removing the ears, as well as that husked and snapped.

² Weighted average price for crop year beginning October 1; 1909-1930 prices are calculated from the 15th of the month prices and weighted by average monthly marketings of crop years 1925-1929, others are season average prices as published by U. S. Department of Agriculture.

³ Preliminary.

Table 80. Cowpeas. Acreage, yield per acre and production, Kentucky, 1924-1939.

Year	Total acreage ¹	Acreage excluding hay ²	Acreage harvested for peas	Yield per acre	Production
	(acres)	(acres)	(acres)	(bushels)	(bushels)
1924	86,000	17,000	7,000	9.0	63,000
1925	65,000	18,000	7,000	8.0	56,000
1926	92,000	21,000	9,000	9.0	81,000
1927	146,000	38,000	15,000	7.5	112,000
1928	89,000	18,000	7,000	10.5	74,000
1929	40,000	11,000	6,000	10.0	60,000
1930	40,000	11,000	4,000	6.5	26,000
1931	63,000	16,000	8,000	10.0	80,000
1932	103,000	23,000	12,000	9.0	108,000
1933	88,000	18,000	9,000	8.0	72,000
1934	83,000	14,000	8,000	9.0	72,000
1935	59,000	13,000	7,000	8.0	56,000
1936	45,000	10,000	6,000	8.5	51,000
1937	78,000	31,000	8,000	8.5	68,000
1938	58,000	24,000	6,000	8.0	48,000
1939 ⁴	53,000	22,000	5,000	8.0	40,000

Data from "Revisions Annual Legume Crops and All Tame Hay, Acreage, Yield and Production, Crop Years 1924-1935" (mimeo. January 1937) and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

¹ Includes allowance for acreage grown with corn and other crops.

² Excluding cowpeas cut for hay. Cowpeas planted in corn and cowpeas grazed or hogged off are included.

³ Solid equivalent of acres for which cowpeas were harvested.

⁴ Preliminary.

Table 81. Oats. Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1909	174,000	17.5	3,045,000	56	1,705,000
1910	180,000	20.0	3,600,000	48	1,728,000
1911	185,000	14.0	2,590,000	53	1,373,000
1912	175,000	20.5	3,588,000	50	1,794,000
1913	195,000	13.5	2,632,000	52	1,369,000
1914	200,000	15.0	3,000,000	56	1,680,000
1915	205,000	20.5	4,202,000	53	2,227,000
1916	220,000	16.0	3,520,000	62	2,182,000
1917	200,000	20.0	4,000,000	85	3,400,000
1918	250,000	19.0	4,750,000	90	4,275,000
1919	280,000	17.5	4,900,000	99	4,851,000
1920	378,000	19.0	7,182,000	89	6,392,000
1921	351,000	16.0	5,616,000	55	3,089,000
1922	274,000	15.5	4,247,000	59	2,506,000
1923	227,000	17.5	3,972,000	63	2,502,000
1924	235,000	18.0	4,230,000	69	2,919,000
1925	206,000	16.5	3,399,000	60	2,039,000
1926	210,000	19.0	3,990,000	57	2,274,000
1927	122,000	15.0	1,830,000	67	1,226,000
1928	172,000	20.0	3,440,000	63	2,167,000
1929	207,000	15.5	3,208,000	62	1,989,000
1930	155,000	13.0	2,015,000	53	1,068,000
1931	217,000	20.0	4,340,000	33	1,432,000
1932	145,000	13.5	1,958,000	26	509,000
1933	102,000	15.5	1,581,000	44	696,000
1934	83,000	14.2	1,179,000	54	637,000
1935	65,000	16.0	1,040,000	45	468,000
1936	78,000	13.5	1,053,000	60	632,000
1937	88,000	21.0	1,848,000	42	776,000
1938 ²	70,000	19.5	1,365,000	35	478,000
1939 ²	56,000	17.0	952,000		

Same sources of information as given for table 79.

For footnotes, same as in table 82.

Table 82. Rye. Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1909	27,000	9.5	256,000	87	223,000
1910	29,000	10.0	290,000	86	249,000
1911	29,000	9.0	261,000	88	230,000
1912	29,000	10.0	290,000	90	261,000
1913	30,000	9.5	285,000	83	237,000
1914	30,000	10.5	315,000	85	268,000
1915	30,000	9.0	270,000	93	251,000
1916	30,000	8.0	240,000	112	269,000
1917	29,000	9.5	276,000	172	475,000
1918	28,000	10.5	294,000	164	482,000
1919	28,000	9.0	252,000	175	441,000
1920	23,000	11.5	264,000	185	488,000
1921	26,000	9.5	247,000	110	272,000
1922	26,000	11.0	286,000	105	300,000
1923	26,000	11.5	299,000	99	296,000
1924	16,000	11.0	176,000	121	213,000
1925	16,000	12.0	192,000	121	232,000
1926	25,000	14.5	362,000	103	373,000
1927	16,000	10.5	168,000	116	195,000
1928	9,000	11.5	104,000	133	138,000
1929	18,000	9.5	171,000	117	200,000
1930	16,000	10.5	168,000	87	146,000
1931	30,000	13.5	405,000	46	186,000
1932	18,000	9.0	162,000	44	71,000
1933	17,000	11.0	187,000	80	150,000
1934	17,000	11.3	192,000	82	157,000
1935	17,000	8.0	136,000	70	95,000
1936	18,000	11.0	198,000	97	192,000
1937	24,000	13.0	312,000	89	278,000
1938	18,000	12.5	225,000	61	137,000
1939 ²	14,000	9.0	126,000		

Data from "Revised Estimates of Rye Acreage, Yield per Acre and Production, 1866-1929" (mimeo. October 1935), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June 1936), statistical sections of the "Yearbook of Agriculture," and "General Crop Report" (December 1939), publications of the U. S. Department of Agriculture.

¹ Weighted average price for crop year beginning July 1; 1909-1930 prices are calculated from 15th of month prices and weighted by average monthly marketings of crop years 1925-1929, others are season average prices as published by the U. S. Department of Agriculture.

² Preliminary.

Table 83. Soybeans. Acreage, yield per acre and production, Kentucky, 1924-1939.

Year	Total acreage ¹	Acreage excluding hay ²	Acreage harvested for beans ³	Yield per acre	Production
	(acres)	(acres)	(acres)	(bushels)	(bushels)
1924	45,000	15,000	9,000	9.5	86,000
1925	56,000	13,000	8,000	8.5	68,000
1926	85,000	20,000	7,000	9.0	63,000
1927	77,000	25,000	6,000	9.0	54,000
1928	104,000	16,000	5,000	10.0	50,000
1929	126,000	30,000	8,000	10.0	80,000
1930	114,000	26,000	9,000	7.5	68,000
1931	143,000	35,000	11,000	11.0	121,000
1932	138,000	31,000	10,000	11.5	115,000
1933	120,000	23,000	8,000	9.5	76,000
1934	100,000	19,000	9,000	10.0	90,000
1935	105,000	19,000	8,000	9.5	76,000
1936	132,000	45,000	9,000	9.5	86,000
1937	106,000	40,000	8,000	11.5	92,000
1938	136,000	55,000	14,000	12.0	168,000
1939 ⁴	151,000	60,000	15,000	12.0	180,000

Data from "Revisions, Annual Legume Crops and All Tame Hay, Acreage, Yield and Production, Crop Years 1924-1935" (mimeo. January 1937) and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

¹ Includes allowance for acreage grown with corn and other crops.

² Excludes soybeans cut for hay. Soybeans planted in corn and soybeans grazed or hogged off are included.

³ Solid equivalent of acres from which soybeans were harvested.

⁴ Preliminary.

Table 84. Sorgo (sorghum) sirup. Acreage harvested for sirup, yield per acre, production, price per gallon and farm value, Kentucky, 1919-1939.

Year	Acreage harvested for sirup	Yield per acre	Production	Price per gallon ¹	Farm value
	(acres)	(gallons)	(gallons)	(cents)	(dollars)
1919	50,000	60	3,000,000	124	3,720,000
1920	40,000	70	2,800,000	107	2,996,000
1921	30,000	65	1,950,000	72	1,404,000
1922	20,000	62	1,240,000	80	992,000
1923	15,000	70	1,050,000	90	945,000
1924	15,000	61	915,000	97	888,000
1925	11,000	59	649,000	96	623,000
1926	15,000	75	1,125,000	80	900,000
1927	11,000	62	682,000	85	580,000
1928	12,000	55	660,000	95	627,000
1929	12,000	55	660,000	100	660,000
1930	12,000	36	432,000	90	389,000
1931	18,000	65	1,170,000	49	573,000
1932	13,000	54	702,000	42	295,000
1933	16,000	60	960,000	49	470,000
1934	16,000	62	992,000	50	496,000
1935	12,000	58	696,000	60	418,000
1936	13,000	45	585,000	70	410,000
1937	13,000	60	780,000	65	507,000
1938	11,000	63	693,000	60	416,000
1939	12,000	60	720,000		

Data from information direct from U. S. Department of Agriculture in addition to "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June 1936), statistical sections of "Yearbook of Agriculture," and "General Crop Report" (December 1939) publications of U. S. Department of Agriculture.

¹ December 1 farm price.

Table 85. Wheat. Acreage, yield per acre, production, price per bushel and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Estimated farm value
	(acres)	(bushels)	(bushels)	(cents)	(dollars)
1909	681,000	12.8	8,717,000	112	9,763,000
1910	750,000	13.0	9,750,000	99	9,652,000
1911	730,000	13.0	9,490,000	84	7,972,000
1912	700,000	10.0	7,000,000	100	7,000,000
1913	670,000	14.0	9,380,000	88	8,254,000
1914	680,000	16.5	11,220,000	90	10,098,000
1915	760,000	11.0	8,360,000	106	8,862,000
1916	750,000	9.0	6,750,000	136	9,180,000
1917	680,000	12.0	8,160,000	230	18,768,000
1918	760,000	14.0	10,640,000	210	22,344,000
1919	840,000	12.5	10,500,000	219	22,995,000
1920	503,000	10.5	5,282,000	242	12,782,000
1921	472,000	10.0	4,720,000	122	5,758,000
1922	402,000	11.5	4,623,000	117	5,409,000
1923	345,000	12.4	4,278,000	109	4,663,000
1924	193,000	10.5	2,026,000	131	2,654,000
1925	193,000	14.5	2,798,000	159	4,449,000
1926	232,000	19.0	4,408,000	135	5,951,000
1927	267,000	10.0	2,670,000	141	3,765,000
1928	134,000	9.5	1,273,000	153	1,948,000
1929	204,000	12.4	2,530,000	123	3,112,000
1930	212,000	14.0	2,968,000	89	2,642,000
1931	286,000	22.0	6,292,000	49	3,083,000
1932	317,000	10.5	3,328,000	48	1,597,000
1933	339,000	12.0	4,068,000	93	3,783,000
1934	403,000	13.0	5,239,000	89	4,663,000
1935	443,000	10.0	4,430,000	86	3,810,000
1936	421,000	14.0	5,894,000	103	6,071,000
1937	552,000	18.5	10,212,000	106	10,825,000
1938 ²	580,000	15.0	8,700,000	63	5,481,000
1939 ²	354,000	11.0	4,071,000		

Same sources of information as given for table 79.

¹ Weighted average price for crop years beginning July 1; 1909-1930 prices are calculated from 15th of month prices and weighted by average monthly marketings of crop years 1925-1929, others are season average prices as published by U. S. Department of Agriculture.

² Preliminary.

Table 86. Grains. Amount sold from Kentucky farms, 1909-1938.

Crop Year	Wheat	Corn	Rye	Oats	Barley
	(1000 bushels)				
1909	7,448	8,335	191	365	10
1910	8,489	7,352	218	432	7
1911	7,977	5,070	177	233	6
1912	5,856	6,825	218	251	12
1913	8,056	2,858	204	158	11
1914	9,877	3,900	239	240	19
1915	7,087	8,910	200	420	34
1916	5,266	5,655	154	246	21
1917	6,809	14,170	198	360	23
1918	9,190	5,705	223	380	25
1919	9,378	4,383	186	343	18
1920	4,380	9,299	202	718	18
1921	3,691	4,825	160	449	19
1922	3,592	6,516	173	340	21
1923	3,207	5,449	174	238	24
1924	1,426	6,323	105	254	12
1925	2,324	7,082	153	272	18
1926	3,772	8,848	260	359	25
1927	1,971	4,025	123	110	14
1928	664	2,826	56	241	4
1929	1,886	3,360	81	160	11
1930	1,603	936	103	60	13
1931	4,230	6,126	144	174	36
1932	1,993	3,479	77	59	20
1933	2,698	3,724	112	47	33
1934	3,746	4,297	124	35	27
1935	2,867	2,714	74	31	46
1936	3,998	3,106	122	32	40
1937	7,571	6,636	175	129	109
1938	5,379	5,112	118	85	122

Data from "Disposition of Wheat, Rye, Buckwheat and Flaxseed, Crop Years, 1909-1936, by states" (mimeo. September, 1938), "Disposition of Feed Grains, Crop Years, 1909-1936, by states" (mimeo. June, 1938), and supplementary mimeographed sheets on same subject for 1937 and 1938, U. S. Department of Agriculture.

HAY

Table 87. Alfalfa hay. Acreage, yield per acre and production, Kentucky, 1919-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1919	56,000	1.45	81,000
1920	52,000	1.40	73,000
1921	56,000	1.50	84,000
1922	62,000	1.45	90,000
1923	64,000	1.55	99,000
1924	61,000	1.35	82,000
1925	61,000	1.55	95,000
1926	68,000	1.80	122,000
1927	87,000	1.60	139,000
1928	89,000	1.60	142,000
1929	98,000	1.70	167,000
1930	82,000	.95	78,000
1931	120,000	1.75	210,000
1932	135,000	1.70	230,000
1933	135,000	1.65	223,000
1934	134,000	1.60	214,000
1935	142,000	1.70	241,000
1936	120,000	.95	114,000
1937	144,000	1.65	238,000
1938	160,000	1.90	304,000
1939 ¹	176,000	1.80	317,000

Data for 1919-1923 from the U. S. Department of Agriculture. Other data from "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1936), 1937 and 1938 December issues of "Crops for Markets," and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ Preliminary.

Table 88. All clover and timothy hay ¹. Acreage, yield per acre and production, Kentucky, 1924-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1924	598,000	1.20	718,000
1925	530,000	.90	477,000
1926	500,000	1.00	500,000
1927	615,000	1.10	676,000
1928	500,000	1.00	500,000
1929	627,000	1.05	658,000
1930	408,000	.55	224,000
1931	443,000	1.00	443,000
1932	456,000	.95	433,000
1933	450,000	1.00	450,000
1934	366,000	.82	300,000
1935	348,000	1.05	365,000
1936	250,000	.55	138,000
1937	350,000	1.05	368,000
1938	364,000	1.20	437,000
1939 ²	350,000	1.10	385,000

Data from "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1936), 1937 and 1938 December issues of "Crops and Markets," and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture.

¹ Excludes sweet clover and lespedeza (Japan clover) hay.

² Preliminary.

Table 89. Grains cut green for hay. Acreage, yield per acre and production, Kentucky, 1919-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1919	98,000	.85	83,000
1920	64,000	.85	54,000
1921	68,000	.70	48,000
1922	44,000	.85	37,000
1923	33,000	.75	25,000
1924	26,000	.95	25,000
1925	37,000	.80	30,000
1926	47,000	.85	40,000
1927	54,000	.90	49,000
1928	78,000	.90	70,000
1929	45,000	.85	38,000
1930	124,000	.55	68,000
1931	125,000	.75	94,000
1932	59,000	.65	38,000
1933	54,000	.85	46,000
1934	41,000	.70	29,000
1935	37,000	1.00	37,000
1936	52,000	.55	29,000
1937	47,000	1.00	47,000
1938	47,000	.95	45,000
1939	47,000	1.00	47,000

Data for 1919-1923 from the U. S. Department of Agriculture. Other data from "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Productions" (mimeo. June, 1936) and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

Table 90. Lespedeza (Japan clover) hay. Acreage, yield per acre and production, Kentucky, 1924-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1924	22,000	1.05	23,000
1925	20,000	.85	17,000
1926	24,000	1.00	24,000
1927	32,000	1.20	38,000
1928	28,000	1.25	35,000
1929	38,000	1.20	46,000
1930	120,000	.75	90,000
1931	176,000	1.15	202,000
1932	280,000	1.15	322,000
1933	350,000	1.20	420,000
1934	455,000	1.00	455,000
1935	550,000	1.10	605,000
1936	248,000	.70	174,000
1937	460,000	1.10	506,000
1938	475,000	1.30	618,000
1939	508,000	1.10	559,000

Data from "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1936), and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

Table 91. Wild hay.¹ Acreage, yield per acre and production, Kentucky, 1912-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1912	14,000	.85	12,000
1913	12,000	.80	10,000
1914	11,000	.75	8,000
1915	14,000	.80	11,000
1916	16,000	.85	14,000
1917	17,000	.90	15,000
1918	20,000	.90	18,000
1919	22,000	.90	20,000
1920	23,000	.80	18,000
1921	26,000	.80	21,000
1922	23,000	.90	21,000
1923	23,000	.90	21,000
1924	23,000	1.00	23,000
1925	17,000	.80	14,000
1926	29,000	.95	28,000
1927	36,000	1.05	38,000
1928	45,000	1.05	47,000
1929	15,000	.95	14,000
1930	14,000	.75	10,000
1931	14,000	.95	13,000
1932	13,000	.90	12,000
1933	12,000	.95	11,000
1934	15,000	.80	12,000
1935	15,000	.95	14,000
1936	38,000	.65	25,000
1937	25,000	1.00	25,000
1938	25,000	1.10	28,000
1939	25,000	1.10	28,000

Data from "Wild Hay Revisions, 1912-1923" (mimeo. June, 1937), "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1936), statistical sections of "Yearbook of Agriculture" and "General Crop Report," (December, 1939), publications of the U. S. Department of Agriculture.

¹ Includes prairie, marsh and salt grasses.

Table 92. Sweet sorghums for forage and hay.¹ Acreage, yield per acre and production, Kentucky, 1919-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1919	44,000	2.00	88,000
1920	52,000	2.60	135,000
1921	41,000	1.90	78,000
1922	33,000	2.40	79,000
1923	30,000	2.20	66,000
1924	29,000	2.10	61,000
1925	29,000	2.30	67,000
1926	30,000	2.20	66,000
1927	23,000	3.00	69,000
1928	24,000	2.60	62,000
1929	25,000	2.20	55,000
1930	44,000	1.60	70,000
1931	72,000	2.50	180,000
1932	54,000	2.30	124,000
1933	51,000	2.30	117,000
1934	57,000	2.30	131,000
1935	48,000	2.00	96,000
1936	50,000	1.85	92,000
1937	50,000	3.00	150,000
1938	40,000	3.10	124,000
1939	37,000	3.00	111,000

Data for 1919-1923 from the U. S. Department of Agriculture. Other data from "General Crop Revisions, Crop Years 1924-1935 of Acreage, Yield and Production" (mimeo. June, 1936) and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

¹ Not included in table on all tame hay.

Table 93. All tame hay. Acreage, yield per acre, production, price per ton and estimated farm value, Kentucky, 1909-1939.

Year	Acreage harvested	Yield per acre ¹	Total production	Price per ton ²	Estimated farm value
	(acres)	(tons)	(tons)	(dollars)	(dollars)
1909	917,000	.99	908,000	12.10	10,987,000
1910	940,000	.95	893,000	12.80	11,430,000
1911	860,000	.80	688,000	17.50	12,040,000
1912	920,000	.95	874,000	15.20	13,285,000
1913	840,000	.80	672,000	16.00	10,752,000
1914	750,000	.80	600,000	17.00	10,200,000
1915	860,000	1.10	946,000	13.10	12,393,000
1916	950,000	1.16	1,045,000	12.90	13,480,000
1917	890,000	1.00	890,000	20.60	18,334,000
1918	1,000,000	1.00	1,000,000	23.00	23,000,000
1919	1,051,000	1.04	1,093,000	26.20	28,637,000
1920	1,065,000	1.05	1,120,000	23.10	25,872,000
1921	1,062,000	.92	977,000	15.70	15,339,000
1922	1,232,000	1.09	1,338,000	14.80	19,802,000
1923	1,220,000	1.07	1,305,000	17.20	22,446,000
1924	1,124,000	1.12	1,255,000	17.90	22,464,000
1925	1,032,000	.88	906,000	17.90	16,217,000
1926	1,175,000	1.01	1,189,000	17.40	20,689,000
1927	1,348,000	1.06	1,423,000	14.60	20,776,000
1928	1,244,000	1.00	1,247,000	15.40	19,204,000
1929	1,272,000	1.04	1,328,000	14.60	19,389,000
1930	1,173,000	.60	709,000	18.00	12,762,000
1931	1,357,000	1.06	1,441,000	11.20	16,139,000
1932	1,387,000	1.05	1,460,000	7.80	11,388,000
1933	1,406,000	1.10	1,553,000	8.40	13,045,000
1934	1,340,000	.99	1,324,000	11.80	15,623,000
1935	1,354,000	1.13	1,527,000	9.10	13,896,000
1936	952,000	.68	643,000	16.30	10,481,000
1937	1,290,000	1.13	1,463,000	11.10	16,239,000
1938	1,319,000	1.30	1,720,000	8.30	14,276,000
1939 ³	1,367,000	1.16	1,582,000		

Data on acreage, yield and production for 1919-1923 from U. S. Department of Agriculture. Other data from "Revisions of Annual Legume Crops and All Tame Hay, Acreage, Yield and Production, Crop Years 1924-1935" (mimeo. January, 1937), statistical sections of "Yearbook of Agriculture" and "General Crop Report" (December, 1939), publications of the U. S. Department of Agriculture. Farm value is calculated.

¹ Yields per acre computed from sums of acreages and productions by kinds of hay.

² Weighted average prices for crop year beginning May 1 are calculated from 15th of month prices and weighted by average monthly marketings of crop years 1925-1929.

³ Preliminary.

Table 94. Miscellaneous tame hay. Acreages, yield per acre and production, Kentucky, 1919-1939.

Year	Acreage harvested	Yield per acre	Production
	(acres)	(tons)	(tons)
1919	261,000	.90	235,000
1920	297,000	.95	282,000
1921	315,000	.90	284,000
1922	395,000	.95	375,000
1923	439,000	.95	417,000
1924	315,000	.95	302,000
1925	294,000	.65	191,000
1926	400,000	.85	340,000
1927	400,000	.85	340,000
1928	390,000	.80	312,000
1929	339,000	.80	271,000
1930	322,000	.50	161,000
1931	338,000	.85	287,000
1932	270,000	.75	202,000
1933	250,000	.80	200,000
1934	194,000	.75	146,000
1935	145,000	.80	116,000
1936	160,000	.50	80,000
1937	176,000	.90	158,000
1938	158,000	.95	150,000
1939	164,000	.80	131,000

Data for 1919-1923 from the U. S. Department of Agriculture. Other data from "General Crop Revisions, Crop Years 1924-1935, Acreage, Yield and Production" (mimeo. June, 1936) and December issues of "Crops and Markets," publications of the U. S. Department of Agriculture.

SEEDS

Table 95. Bluegrass seed. Production, yield per acre (1925-1939), price per bushel paid to growers and farm value of rough, cured seed, Kentucky and Ohio 1910-1939.

Year	Production	Yield per acre	Price per bushel	Farm value
	(bushels)	(bushels)	(dollars)	(dollars)
1910	200,000		1.45	290,000
1911	350,000		1.70	595,000
1912	1,500,000		.60	900,000
1913	175,000		.60	105,000
1914	700,000		.45	315,000
1915	350,000		.60	210,000
1916	250,000		.70	175,000
1917	200,000		1.50	300,000
1918	350,000		1.50	525,000
1919	350,000		1.60	560,000
1920	400,000		1.80	720,000
1921	175,000		2.25	394,000
1922	700,000		1.35	945,000
1923	650,000		1.25	812,000
1924	325,000		1.75	569,000
1925	100,000	3.5	1.75	175,000
1926	1,300,000	14.0	1.20	1,560,000
1927	450,000	8.5	.70	315,000
1928	75,000	5.0	1.25	94,000
1929	450,000	7.0	1.20	540,000
1930	125,000	4.5	1.40	175,000
1931	2,300,000	17.0	.70	1,610,000
1932	400,000	4.2	.40	160,000
1933	600,000	7.0	.50	300,000
1934	175,000	4.0	.75	131,000
1935	900,000	9.0	.50	450,000
1936	250,000	5.0	.70	175,000
1937	1,400,000	14.0	.50	700,000
1938	200,000	6.5	.50	100,000
1939 ¹	240,000	6.5	.85	204,000

Data from "Seed Reporter," "Market Reporter," "Weather, Crops and Markets," "Seed Statistics" and numerous mimeograph releases, U. S. Department of Agriculture; certain revisions and additions to the published data were also obtained direct from the Division of Agricultural Statistics, U. S. Department of Agriculture. Farm value is calculated.

¹ Preliminary.

Table 96. Clover seed (red and alsike). Acreage, yield per acre, production price per bushel and farm value, Kentucky. 1929-1939.

Year	Acreage harvested	Yield per acre	Production	Price per bushel ¹	Farm value
	(acres)	(bushels)	(bushels)	(dollars)	(dollars)
1929	16,000	1.6	25,600	14.00	358,000
1930	3,000	1.1	3,300	14.00	47,000
1931	1,000	2.0	2,000	8.50	17,000
1932	1,000	1.5	1,500	5.50	8,000
1933	1,000	1.6	1,600	6.60	11,000
1934	1,000	1.5	1,500	10.50	16,000
1935	9,500	1.2	11,400	9.80	112,000
1936	4,000	1.0	4,000	15.10	60,000
1937	6,000	1.5	9,000	17.60	158,000
1938	15,000	1.5	22,000	8.00	176,000
1939 ²	6,000	1.5	9,000		

Data from "Seed Statistics" (March 1936), statistical sections of "Yearbook Agriculture," and "General Crop Report" (December 1939) U. S. Department Agriculture.

¹ Weighted average price for season, except the December 1 price for 1929.

² Preliminary.

Table 97. Lespedeza seed. Acreage, yield per acre, production, price per 100 pounds and farm value, Kentucky 1929-1939.

Year	Acreage harvested	Yield per acre	Production	Price per 100 pounds ¹	Farm value
	(acres)	(pounds)	(pounds)	(dollars)	(dollars)
1929	4,000	200	800,000	11.00	88,000
1930	10,000	150	1,500,000	11.00	165,000
1931	23,000	200	4,600,000	9.20	423,000
1932	46,000	212½	9,775,000	4.00	391,000
1933	91,000	200	18,200,000	4.60	837,200
1934	91,000	175	15,925,000	5.80	923,650
1935	118,000	200	23,600,000	5.40	1,274,400
1936	88,000	150	13,200,000	13.20	1,742,400
1937	132,000	200	26,400,000	4.70	1,241,000
1938 ²	166,000	300	49,800,000	3.00	1,494,000
1939 ²	116,000	185	21,460,000		

¹ Data from "Seed Statistics" (March 1936), statistical sections of "Yearbooks of Agriculture," and "General Crop Report" (December 1939), U. S. Department of Agriculture.

² Prices 1929-1934 are December 1 prices per bushel converted at the rate of 5 pounds per bushel. Other prices are season average price received by farmers.

³ Preliminary.

Table 98. Orchard grass seed. Production, yield per acre (1925-1939), price per bushel paid to growers and farm value of thresher-run seed, Kentucky, Ohio and Indiana district, 1910-1939.

Year	Production	Yield per acre	Price per bushel	Farm value
	(bushels)	(bushels)	(dollars)	(dollars)
1910	120,000		1.75	210,000
1911	260,000		1.80	468,000
1912	240,000		1.25	300,000
1913	150,000		1.60	240,000
1914	165,000		1.70	280,000
1915	160,000		1.80	288,000
1916	200,000		2.00	400,000
1917	175,000		2.20	385,000
1918	250,000		2.10	525,000
1919	225,000		2.00	450,000
1920	200,000		1.50	300,000
1921	125,000		1.60	200,000
1922	200,000		.95	190,000
1923	175,000		1.25	219,000
1924	60,000		1.65	99,000
1925	40,000	9.5	1.40	56,000
1926	150,000	17.0	1.25	188,000
1927	75,000	12.0	1.25	94,000
1928	50,000	9.5	1.65	82,000
1929	55,000	11.5	1.25	69,000
1930	50,000	8.5	1.35	68,000
1931	200,000	19.5	.60	120,000
1932	75,000	11.5	.50	38,000
1933	100,000	15.75	.75	75,000
1934	75,000	9.0	1.10	82,000
1935	125,000	13.0	.85	106,000
1936	75,000	9.25	1.40	105,000
1937	200,000	20.0	1.05	210,000
1938	75,000	8.6	1.35	101,000
1939 ¹	175,000	14.0	1.25	219,000

Data from "Seed Reporter," "Market Reporter," "Weather, Crops and Markets," "Seed Statistics" and numerous mimeograph releases, U. S. Department of Agriculture; certain revisions and additions to the published data were also obtained direct from the Division of Agricultural Statistics, U. S. Department of Agriculture. Farm value is calculated.

¹ Preliminary.

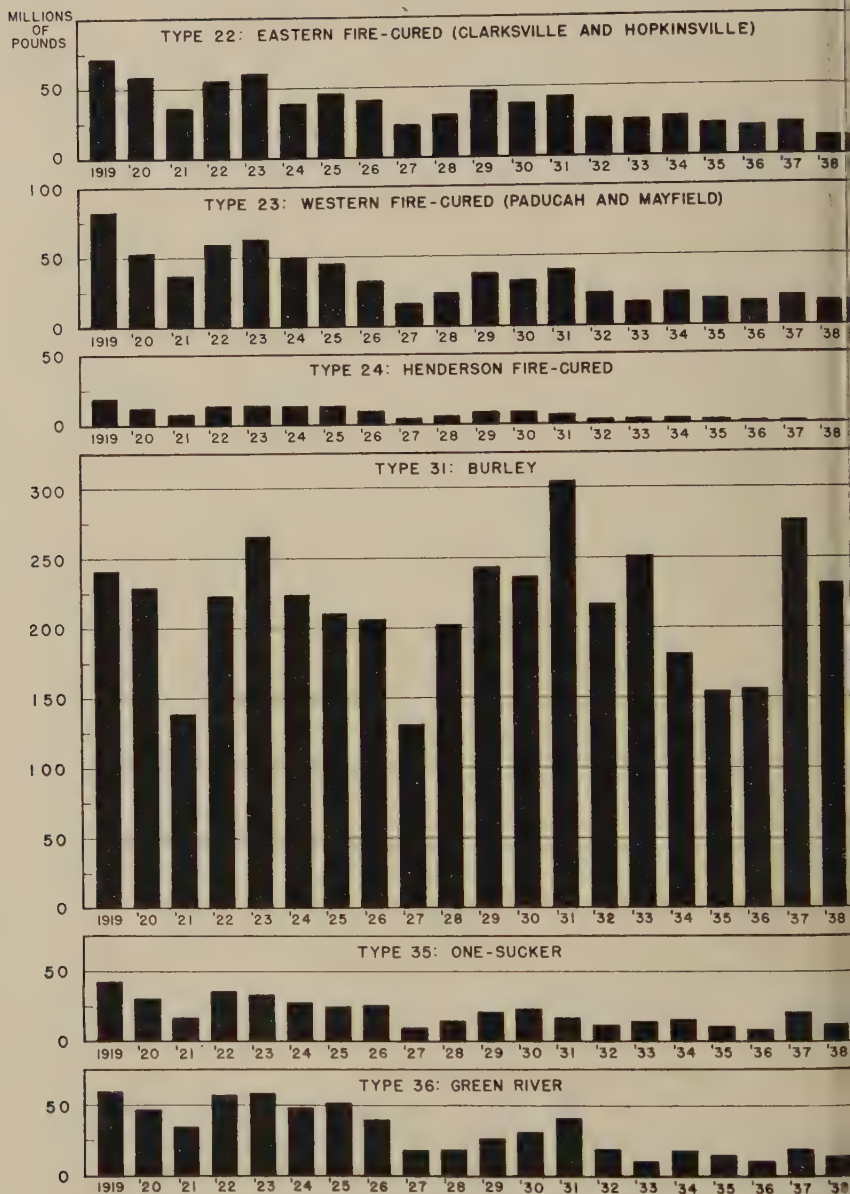


Figure 29. Tobacco. Production of six types, Kentucky, 1919-1938.

The trend in Kentucky's production of all types of tobacco, except Burley, has been downward since 1919. The production of Burley has fluctuated considerably but showed no definite trend from 1919 to 1938.

TOBACCO

Table 99. Tobacco, type 22 (Eastern fire-cured). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	96,000	757	72,638,000	16.9	12,262,000
1920	75,000	787	59,008,000	10.5	6,189,000
1921	46,000	794	36,533,000	16.8	6,132,000
1922	72,200	780	56,319,000	14.8	8,359,000
1923	77,500	799	61,897,000	11.4	7,035,000
1924	49,500	806	39,900,000	14.1	5,631,000
1925	58,000	798	46,260,000	8.0	3,711,000
1926	50,000	825	41,247,000	7.0	2,903,000
1927	35,000	691	24,194,000	16.6	4,021,000
1928	44,000	715	31,452,000	15.2	4,767,000
1929	56,000	850	47,600,000	13.0	6,188,000
1930	55,000	700	38,500,000	7.5	2,888,000
1931	53,000	800	42,400,000	5.5	2,332,000
1932	36,000	765	27,540,000	6.1	1,680,000
1933	35,000	740	25,900,000	10.0	2,590,000
1934	32,500	870	28,275,000 ²	12.2	3,236,000
1935	30,000	795	23,850,000	8.8	2,099,000
1936	27,000	790	21,330,000	12.6	2,688,000
1937	29,000	840	24,360,000	10.3	2,596,000
1938	19,000	630	11,970,000	6.9	826,000
1939 ³	18,000	800	14,400,000	9.9	1,426,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics," Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 1,850,000 pounds not marketed.

³ Preliminary.

Table 100. Tobacco, type 23 (Western fire-cured). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	109,000	760	82,840,000	15.0	12,426,000
1920	68,000	790	53,720,000	9.0	4,835,000
1921	45,000	840	37,800,000	14.0	5,292,000
1922	72,000	825	59,400,000	13.3	7,900,000
1923	78,500	810	63,585,000	10.8	6,867,000
1924	61,500	812	49,938,000	11.0	5,493,000
1925	58,000	780	45,240,000	6.7	3,031,000
1926	40,000	815	32,600,000	6.0	1,956,000
1927	21,700	750	16,275,000	12.2	1,986,000
1928	34,000	732	24,888,000	12.6	3,136,000
1929	46,000	825	37,950,000	10.0	3,795,000
1930	47,000	700	32,900,000	5.3	1,744,000
1931	50,000	800	40,000,000	3.9	1,560,000
1932	30,000	775	23,250,000	4.5	1,046,000
1933	26,000	630	16,380,000	6.7	1,097,000
1934	27,500	840	23,100,000 ²	8.9	1,940,000
1935	25,000	790	19,750,000	7.4	1,462,000
1936	23,500	750	17,625,000	9.3	1,639,000
1937	26,000	810	21,060,000	9.0	1,895,000
1938	21,600	775	16,740,000	6.8	1,138,000
1939 ³	20,600	830	17,098,000	8.5	1,453,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics," Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 1,300,000 pounds not marketed.

³ Preliminary.

Table 101. Tobacco, type 24 (Henderson fire-cured). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	25,000	780	19,500,000	16.0	3,120,000
1920	15,300	820	12,546,000	10.0	1,255,000
1921	9,700	855	8,294,000	15.0	1,244,000
1922	15,800	893	14,109,000	15.0	2,116,000
1923	16,500	880	14,520,000	12.0	1,742,000
1924	17,200	825	14,190,000	12.0	1,703,000
1925	18,000	775	13,950,000	7.3	1,018,000
1926	11,000	896	9,856,000	7.4	729,000
1927	6,500	646	4,199,000	9.7	407,000
1928	8,000	750	6,000,000	13.9	834,000
1929	11,000	850	9,350,000	9.5	888,000
1930	13,000	745	9,685,000	6.9	668,000
1931	9,000	800	7,200,000	4.0	288,000
1932	5,000	775	3,875,000	3.4	132,000
1933	4,000	740	2,960,000	6.5	192,000
1934	4,500	875	3,938,000 ²	8.0	303,000
1935	3,600	840	3,024,000	6.4	194,000
1936	2,700	730	1,971,000	8.9	175,000
1937	2,500	850	2,125,000	7.2	153,000
1938	1,600	875	1,400,000	7.1	99,000
1939 ³	800	830	664,000	7.0	46,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 150,000 pounds not marketed.

³ Preliminary.

Table 102. Tobacco, type 31 (Burley). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	287,000	840	241,080,000	34.0	81,967,000
1920	298,000	770	229,460,000	13.3	30,518,000
1921	190,000	735	139,650,000	21.0	29,326,000
1922	260,000	860	223,600,000	26.5	59,254,000
1923	305,000	870	265,350,000	19.5	51,743,000
1924	265,000	845	223,925,000	20.1	45,009,000
1925	260,000	810	210,600,000	17.8	37,487,000
1926	250,000	825	206,250,000	13.3	27,431,000
1927	185,000	705	130,425,000	26.3	34,302,000
1928	250,000	810	202,500,000	30.7	62,168,000
1929	310,000	785	243,350,000	21.4	52,077,000
1930	335,000	705	236,175,000	15.0	35,426,000
1931	365,000	835	304,775,000	8.6	26,211,000
1932	300,000	725	217,500,000	12.2	26,535,000
1933	350,000	715	250,250,000	10.7	26,777,000
1934	220,000	825	181,500,000 ²	17.3	28,874,000
1935	202,000	765	154,530,000	18.9	29,206,000
1936	225,000	690	155,250,000	35.8	55,580,000
1937	309,000	895	276,555,000	20.4	56,417,000
1938	286,000	810	231,660,000	19.5	45,174,000
1939 ³	305,000	900	274,500,000	17.7	48,586,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 14,600,000 pounds not marketed.

³ Preliminary.

Table 103. Tobacco, type 35 (One Sucker). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	54,000	795	42,930,000	14.5	6,225,000
1920	39,000	800	31,200,000	7.5	2,340,000
1921	20,000	875	17,500,000	12.6	2,205,000
1922	41,000	870	35,670,000	13.2	4,708,000
1923	42,500	815	34,638,000	10.0	3,464,000
1924	35,500	785	27,868,000	11.5	3,205,000
1925	30,000	833	24,990,000	8.8	2,199,000
1926	28,000	920	25,760,000	6.7	1,726,000
1927	13,900	705	9,800,000	11.0	1,078,000
1928	20,000	750	15,000,000	12.7	1,905,000
1929	25,000	850	21,250,000	10.6	2,252,000
1930	30,000	790	23,700,000	7.0	1,659,000
1931	22,000	785	17,270,000	3.4	587,000
1932	15,000	810	12,150,000	4.9	595,000
1933	19,000	780	14,820,000	7.0	1,037,000
1934	17,500	900	15,750,000 ²	7.0	1,052,000
1935	12,400	835	10,354,000	8.1	839,000
1936	12,500	725	9,062,000	16.6	1,504,000
1937	23,000	915	21,045,000	7.4	1,557,000
1938	16,200	775	12,555,000	5.7	716,000
1939 ³	20,000	925	18,500,000	6.7	1,240,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics," Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 720,000 pounds not marketed.

³ Preliminary.

Table 104. Tobacco, type 36 (Green River). Acreage, yield per acre, production, price per pound and farm value, Kentucky, 1919-1939.

Year	Acreage	Yield per acre	Production	Price per pound ¹	Farm value
	(acres)	(pounds)	(pounds)	(cents)	(dollars)
1919	77,000	780	60,060,000	16.0	9,610,000
1920	59,700	796	47,521,000	9.0	4,277,000
1921	39,300	881	34,623,000	15.0	5,193,000
1922	64,000	893	57,152,000	16.0	9,144,000
1923	67,000	880	58,960,000	11.0	6,486,000
1924	57,300	830	47,559,000	11.6	5,517,000
1925	60,000	850	51,000,000	6.9	3,519,000
1926	47,000	851	39,997,000	7.4	2,960,000
1927	27,900	649	18,107,000	9.1	1,648,000
1928	27,000	700	18,900,000	11.5	2,174,000
1929	32,000	840	26,880,000	10.7	2,876,000
1930	39,000	785	30,615,000	8.9	2,725,000
1931	46,000	880	40,480,000	3.3	1,336,000
1932	24,000	825	19,800,000	3.4	673,000
1933	15,000	740	11,100,000	7.9	877,000
1934	21,000	890	18,690,000 ²	8.1	1,417,000
1935	18,000	845	15,210,000	7.3	1,110,000
1936	16,000	700	11,200,000	14.4	1,613,000
1937	22,000	900	19,800,000	9.0	1,782,000
1938	17,000	870	14,790,000	9.6	1,420,000
1939 ³	20,500	875	17,938,000	7.4	1,327,000

Data from Statistical Bulletin No. 58, "First Annual Report on Tobacco Statistics," Annual Report on Tobacco Statistics" (September 1939) and "General Crop Report" (June, 1940), publications of the U. S. Department of Agriculture.

¹ For year beginning October 1.

² Includes approximately 1,200,000 pounds not marketed.

³ Preliminary.

LIVESTOCK ON FARMS IN KENTUCKY

Estimates of the number of livestock on farms in Kentucky, January 1 of each year, are published by the Bureau of Agricultural Economics of the United States Department of Agriculture. Information obtained thru the census of agriculture serves as a basis for these estimates but year-to-year changes in the number of livestock are obtained from farmers by the use of questionnaires. Because estimates are carried forward from one census period to the next, it frequently is necessary to revise the estimates when new census data become available. The latest revised number, value per head, and total value of livestock on farms in Kentucky, January 1 of the years prior to 1920, are given in *Livestock on Farms, January 1, 1867-1919, Revised Estimates Number, Value per Head, and Total Value by States and Divisions* (January, 1938), published by the United States Department of Agriculture. More recent estimates may be obtained from the Statistical Yearbooks of the United States Department of Agriculture or from the February issues of *Crops and Markets*.

Livestock production, either in the form of meat or of livestock products, is more difficult to estimate than the production of crops. The number of livestock on farms January 1 does not reflect livestock production accurately but no better figures covering a long period of years are available. In Tables 111, 113 and 114 some estimates of the production of livestock and livestock products are given.

Table 105. All cattle and calves.¹ Number on farms, farm value per head and total farm value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	950,000	25.20	23,897,000
1911	910,000	27.60	25,103,000
1912	880,000	27.30	23,993,000
1913	860,000	31.60	27,176,000
1914	909,000	35.40	32,177,000
1915	953,000	36.50	35,012,000
1916	976,000	36.60	35,745,000
1917	1,075,000	39.80	42,832,000
1918	1,150,000	47.30	54,420,000
1919	1,205,000	53.60	64,546,000
1920	1,093,000	49.20	53,776,000
1921	1,088,000	37.10	40,365,000
1922	1,074,000	26.30	28,246,000
1923	1,000,000	28.10	28,100,000
1924	970,000	26.60	25,802,000
1925	971,000	26.80	26,023,000
1926	942,000	30.60	28,825,000
1927	956,000	35.40	33,842,000
1928	990,000	46.90	46,431,000
1929	1,015,000	51.40	52,171,000
1930	990,000	49.40	48,906,000
1931	1,010,000	31.80	32,118,000
1932	1,059,000	23.20	24,569,000
1933	1,109,000	18.00	19,962,000
1934	1,168,000	16.40	19,148,000
1935	1,212,000	18.90	22,861,000
1936	1,212,000	29.90	36,292,000
1937	1,127,000	30.00	33,850,000
1938	1,172,000	31.20	36,597,000
1939 ²	1,195,000	33.40	39,884,000
1940 ²	1,243,000	35.30	43,920,000

Data from "Revised Estimates, Number, Value per Head, Total Value of Live-Stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "Crops and Markets," U. S. Department of Agriculture.

¹ Including cows and heifers kept for milk.

² Preliminary.

Table 106. Hogs.¹ Number on farms, farm value per head and total farm value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	1,360,000	6.80	9,248,000
1911	1,500,000	7.20	10,800,000
1912	1,600,000	5.40	8,640,000
1913	1,405,000	7.10	9,976,000
1914	1,300,000	7.70	10,010,000
1915	1,300,000	7.20	9,360,000
1916	1,360,000	6.50	8,840,000
1917	1,400,000	8.90	12,460,000
1918	1,715,000	14.50	24,868,000
1919	1,900,000	16.00	30,400,000
1920	1,504,000	13.60	20,454,000
1921	1,320,000	10.40	13,728,000
1922	1,161,000	7.90	9,172,000
1923	1,273,000	9.20	11,712,000
1924	1,185,000	7.40	8,769,000
1925	932,000	9.40	8,761,000
1926	839,000	12.40	10,404,000
1927	965,000	14.40	13,896,000
1928	1,040,000	9.90	10,296,000
1929	988,000	8.50	8,398,000
1930	920,000	9.60	8,832,000
1931	828,000	7.60	6,293,000
1932	1,058,000	5.90	6,242,000
1933	1,306,000	4.00	5,224,000
1934	1,325,000	3.45	4,557,000
1935	1,035,000	5.50	5,714,000
1936	1,004,000	9.40	9,440,000
1937	1,004,000	8.90	8,932,000
1938	1,024,000	9.10	9,324,000
1939 ²	1,167,000	9.00	10,546,000
1940 ²	1,400,000	6.20	8,738,000

Data from "Revised Estimates, Number, Value per Head, Total Value of Live-Stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "Crops and Markets," U. S. Department of Agriculture.

¹ Including pigs.

² Preliminary.

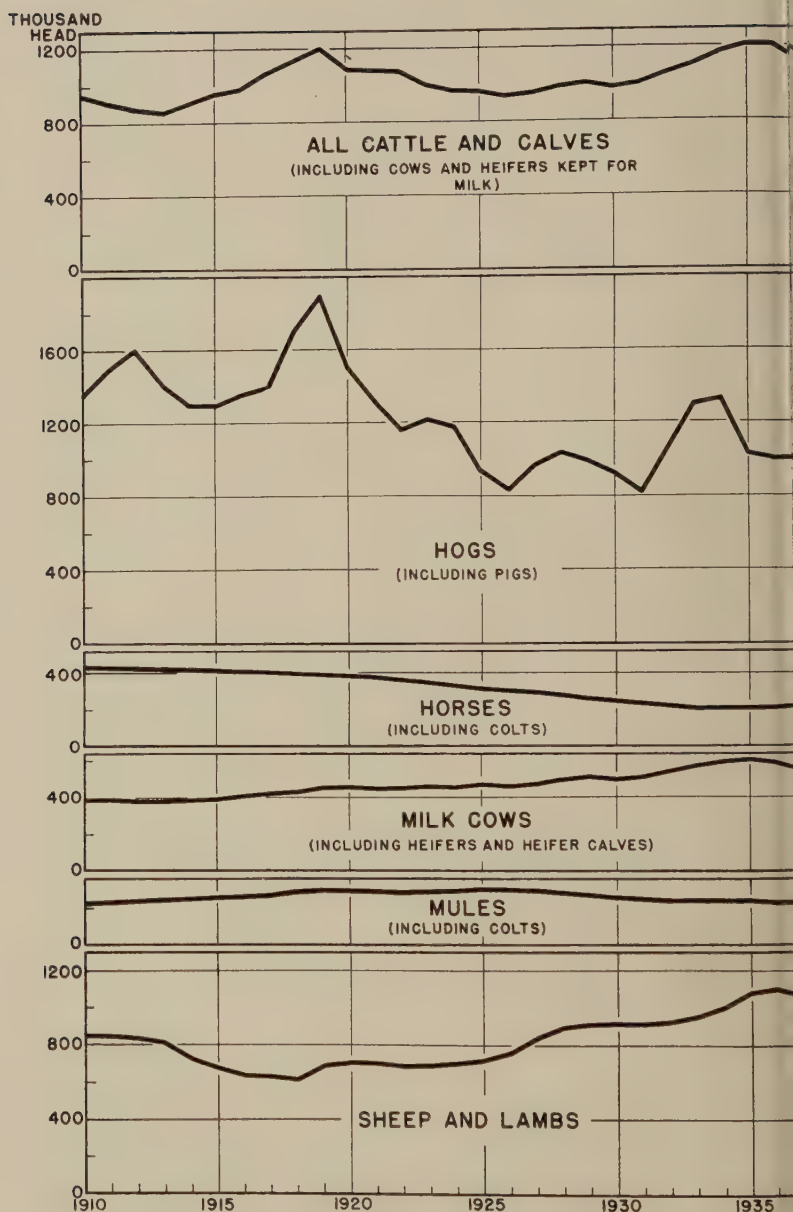


Figure 30. Livestock. Number on farms, January 1, Kentucky, 1910-1935.

Since 1910, the numbers of hogs and horses on farms in Kentucky declined while the numbers of cattle and calves, milk cows, and sheep and lambs have increased. The number of mules varied but little and was about the same as in 1910.

Table 107. Horses.¹ Number on farms, farm value per head and total farm value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	435,000	105.00	45,675,000
1911	431,000	108.00	46,548,000
1912	428,000	107.00	45,796,000
1913	425,000	104.00	44,200,000
1914	420,000	103.00	43,260,000
1915	415,000	95.00	39,425,000
1916	410,000	90.00	36,900,000
1917	402,000	93.00	37,386,000
1918	397,000	101.00	40,097,000
1919	390,000	104.00	40,560,000
1920	382,000	105.00	39,958,000
1921	370,000	87.00	32,064,000
1922	360,000	69.00	24,682,000
1923	343,000	66.00	22,542,000
1924	330,000	56.00	18,516,000
1925	314,000	50.00	15,700,000
1926	305,000	50.00	15,250,000
1927	293,000	47.00	13,771,000
1928	280,000	53.00	14,840,000
1929	258,000	56.00	14,448,000
1930	248,000	60.00	14,880,000
1931	233,000	51.00	11,883,000
1932	221,000	47.00	10,387,000
1933	211,000	47.00	9,917,000
1934	208,000	58.00	12,143,000
1935	210,000	80.00	16,724,000
1936	214,000	99.00	21,266,000
1937	225,000	104.00	23,303,000
1938	232,000	101.00	23,500,000
1939	237,000	94.00	22,204,000
1940 ²	237,000	87.00	20,585,000

Data from "Revised Estimates, Number, Value per Head, Total Value of Live-Stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "Crops and Markets," U. S. Department of Agriculture.

¹ Including colts.

² Preliminary.

Table 108. Milk cows.¹ Number on farms, farm value per head and total farm value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	390,000	32.70	12,753,000
1911	390,000	36.50	14,235,000
1912	382,000	35.30	13,485,000
1913	380,000	38.80	14,744,000
1914	382,000	44.50	16,999,000
1915	390,000	45.50	17,745,000
1916	406,000	44.80	18,189,000
1917	418,000	49.50	20,691,000
1918	435,000	61.00	26,535,000
1919	452,000	72.00	32,544,000
1920	455,000	69.00	31,395,000
1921	450,000	54.00	24,300,000
1922	450,000	38.00	17,100,000
1923	462,000	38.00	17,556,000
1924	457,000	36.00	16,452,000
1925	473,000	35.00	16,555,000
1926	465,000	38.00	17,670,000
1927	476,000	45.00	21,420,000
1928	496,000	60.00	29,760,000
1929	512,000	65.00	33,280,000
1930	498,000	64.00	31,872,000
1931	511,000	40.00	20,440,000
1932	543,000	30.00	16,290,000
1933	575,000	23.00	13,225,000
1934	595,000	21.00	12,495,000
1935	610,000	24.00	14,640,000
1936	586,000	37.00	21,682,000
1937	557,000	38.00	21,166,000
1938	551,000	40.00	22,040,000
1939	540,000	43.00	23,220,000
1940 ²	540,000	45.00	24,300,000

Data from "Revised Estimates, Number, Value per Head, Total Value of Live-Stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "Crops and Markets," U. S. Department of Agriculture.

¹ Including heifers and heifer calves being kept for milk cows.

² Preliminary.

Table 109. Mules.¹ Number on farms, farm value per head and total value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	220,000	118.00	25,960,000
1911	230,000	122.00	28,060,000
1912	237,000	118.00	27,966,000
1913	240,000	120.00	28,800,000
1914	245,000	118.00	28,910,000
1915	254,000	106.00	26,924,000
1916	265,000	102.00	27,030,000
1917	275,000	112.00	30,800,000
1918	290,000	122.00	35,380,000
1919	298,000	127.00	37,846,000
1920	293,000	130.00	38,026,000
1921	285,000	111.00	31,689,000
1922	280,000	82.00	22,932,000
1923	287,000	77.00	22,041,000
1924	293,000	67.00	19,545,000
1925	301,000	63.00	18,963,000
1926	304,000	63.00	19,152,000
1927	301,000	58.00	17,458,000
1928	284,000	67.00	19,028,000
1929	270,000	69.00	18,630,000
1930	257,000	77.00	19,789,000
1931	246,000	64.00	15,744,000
1932	240,000	59.00	14,160,000
1933	240,000	59.00	14,160,000
1934	240,000	72.00	17,310,000
1935	240,000	101.00	24,148,000
1936	235,000	123.00	28,879,000
1937	233,000	129.00	30,066,000
1938	231,000	124.00	28,534,000
1939	231,000	116.00	26,711,000
1940 ²	233,000	105.00	24,495,000

Data from "Revised Estimates, Number, Value per Head, Total Value of stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "and Markets," U. S. Department of Agriculture.

¹ Including mule colts.

² Preliminary.

Table 110. Sheep and lambs. Number on farms, farm value per head and farm value, Kentucky, January 1, 1910-1940.

Year	Number	Value per head	Farm value
	(head)	(dollars)	(dollars)
1910	852,000	4.00	3,408,000
1911	852,000	4.10	3,493,000
1912	835,000	3.70	3,090,000
1913	818,000	4.00	3,272,000
1914	736,000	4.20	3,091,000
1915	677,000	4.20	2,843,000
1916	636,000	4.90	3,116,000
1917	636,000	7.10	4,516,000
1918	617,000	11.20	6,910,000
1919	691,000	13.10	9,052,000
1920	708,000	11.20	7,944,000
1921	701,000	6.40	4,505,000
1922	687,000	5.00	3,409,000
1923	690,000	7.00	4,812,000
1924	700,000	7.90	5,529,000
1925	715,000	8.90	6,364,000
1926	751,000	10.10	7,585,000
1927	827,000	10.70	8,849,000
1928	895,000	11.20	10,024,000
1929	910,000	11.40	10,374,000
1930	915,000	10.40	9,516,000
1931	915,000	6.50	5,948,000
1932	924,000	4.70	4,343,000
1933	953,000	3.90	3,717,000
1934	1,004,000	4.45	4,479,000
1935	1,080,000	4.75	5,120,000
1936	1,102,000	6.70	7,365,000
1937	1,047,000	6.50	6,755,000
1938	1,110,000	7.00	7,770,000
1939	1,143,000	6.90	7,896,000
1940 ¹	1,189,000	7.40	8,844,000

Data from "Revised Estimates, Number, Value per Head, Total Value of stock on Farms, Jan. 1, 1867-1919" (Jan. 1938), and February issues of "and Markets," U. S. Department of Agriculture.

¹ Preliminary.

Table 111. Meat animals. Production of cattle, calves, hogs, sheep and lambs, Kentucky, 1924-1938.

Year	Cattle	Calves	Hogs	Sheep	Lambs
(Thousands of pounds)					
1924	144,225	30,460	227,630	4,135	37,390
1925	153,550	30,410	228,585	2,530	38,700
1926	143,675	29,900	260,025	7,070	37,600
1927	156,175	29,850	307,575	5,925	48,240
1928	145,325	30,930	271,247	4,570	48,895
1929	162,125	28,840	225,975	5,980	50,965
1930	157,675	25,530	208,900	4,630	50,905
1931	152,300	29,710	231,175	3,580	53,860
1932	166,300	31,200	277,850	2,720	58,625
1933	174,975	33,990	303,604	5,135	60,690
1934	206,035	34,700	266,945	5,215	58,835
1935	204,040	39,960	233,665	5,530	61,675
1936	210,345	38,220	261,725	5,530	57,685
1937	213,225	31,700	270,735		69,590 ²
1938 ¹	260,080 ³		293,890		67,020 ²

From "Farm Production and Income from Meat Animals, 1924-1935, by States" (mimeo. September 1936), "Farm Production from Meat Animals by States," 1935-1936 (mimeo. June 1937), 1936-1937 (mimeo. June 1938), 1937-1938 (April 1939), U. S. Department of Agriculture.

¹ Preliminary estimate.

² Sheep and lambs.

³ Cattle and calves.

Table 112. Chickens. Number on farms, farm value per head and total farm value, Kentucky, January 1, 1924-1940.

Year	Number	Value per head	Farm value
	(head)	(cents)	(dollars)
1924	12,109,000	65	7,871,000
1925	11,722,000	69	8,088,000
1926	11,847,000	74	8,767,000
1927	12,698,000	80	10,158,000
1928	12,766,000	77	9,830,000
1929	11,160,000	82	9,151,000
1930	11,790,000	88	10,375,000
1931	11,157,000	60	6,694,000
1932	10,883,000	54	5,877,000
1933	11,569,000	35	4,049,000
1934	11,536,000	33	3,807,000
1935	11,284,000	46	5,191,000
1936	11,172,000	67	7,485,000
1937	11,600,000	53	6,148,000
1938	10,499,000	62	6,509,000
1939	11,128,000	55	6,120,000
1940 ¹	10,954,000	48	5,258,000

Data from "Farm Production and Disposition of Chickens and Eggs, 1909-1924" (mimeo. June 1939), "Farm Production and Disposition of Chickens and Eggs, 1925-1937, by States" (mimeo. Dec. 1938), and Feb. 1940 issue of "Crops and Markets," Publications of the U. S. Department of Agriculture.

¹ Preliminary.

Table 113. Eggs. Production, farm price and value of eggs produced on farms in Kentucky 1924-1938.

Year	Production	Price per dozen ¹	Farm value
	(number)	(cents)	(dollars)
1924	808,000,000	24.3	16,362,000
1925	805,000,000	28.2	18,918,000
1926	886,000,000	27.1	20,009,000
1927	961,000,000	23.2	18,579,000
1928	786,000,000	26.6	17,423,000
1929	766,000,000	28.1	17,937,000
1930	805,000,000	22.2	14,892,000
1931	788,000,000	15.9	10,441,000
1932	753,000,000	11.9	7,467,000
1933	738,000,000	11.5	7,072,000
1934	731,000,000	15.1	9,198,000
1935	766,000,000	20.7	13,214,000
1936	739,000,000	19.7	12,132,000
1937	809,000,000	19.4	13,079,000
1938	819,000,000	17.7	12,080,000

Data from "Farm Production and Disposition of Chickens and Eggs, 1909-1924" (mimeo June 1939), "Farm Production and Disposition of Chickens and Eggs, 1925-1937, by States" (mimeo December 1938), and "Agricultural Statistics, 1939," U. S. Department of Agriculture.

¹ Weighted average for year.

Table 114. Turkeys. Number raised on farms, value per head and total farm value, Kentucky, 1929-1938.

Year	Number raised	Value per head ¹	Farm value
	(head)	(dollars)	(dollars)
1929	383,000	2.92	1,118,000
1930	425,000	2.27	965,000
1931	425,000	2.17	922,000
1932	520,000	1.56	811,000
1933	560,000	1.34	750,000
1934	590,000	1.94	1,145,000
1935	510,000	2.63	1,341,000
1936	590,000	1.88	1,109,000
1937	520,000	2.50	1,300,000
1938	468,000	2.38	1,114,000

Data from "Turkeys Raised on Farms, 1929-1938, Number and Value by Region and States" (mimeo. March 1939), U. S. Department of Agriculture.

¹ Weighted average price received by producers.

MISCELLANEOUS DATA

Table 115. Farm real estate. Index numbers of estimated value per acre, Kentucky, March 1, 1912-1939.

Year	1912-1914 = 100	1921-1929 = 100 ¹	March 1	1912-1914 = 100	1921-1929 = 100 ¹
1912	97	68	1926	139	98
1913	100	70	1927	134	94
1914	103	72	1928	130	91
1915	100	70	1929	129	90
1916	111	78	1930	127	89
1917	127	89	1931	115	81
1918	146	102	1932	97	68
1919	170	119	1933	80	56
1920	200	140	1934	81	57
1921	172	121	1935	87	61
1922	151	106	1936	89	62
1923	147	103	1937	98	69
1924	141	99	1938	103	72
1925	140	98	1939	107	75

¹From Circular 417, "Farm Real Estate Situation, 1935-1936," and April 1939 Crops and Markets," U. S. Department of Agriculture.

²Converted from 1912-1914 base by multiplying by .70146.

Table 116. Pasture. Condition 1st of month, Kentucky, 1914-1939. (Percent normal.)

Year	May	June	July	Aug.	Sept.	Oct.
1914	89	82	59	48		
1915	71	87	96	96	103	107
1916	84	89	96	91	93	85
1917	88	72	84	87	85	82
1918	91	96	85	80	67	85
1919	92	98	95	80	72	65
1920	80	90	90	88	97	96
1921	93	90	78	65	85	96
1922	96	98	90	91	76	74
1923	78	85	93	86	97	93
1924	79	86	92	90	82	83
1925	89	80	75	75	58	62
1926	69	73	81	70	91	92
1927	92	95	96	89	89	71
1928	65	73	90	92	90	72
1929	90	91	91	83	69	80
1930	69	68	50	27	26	43
1931	82	85	78	73	84	79
1932	79	74	76	73	72	73
1933	77	90	68	69	79	84
1934	66	59	66	64	82	78
1935	83	89	93	91	91	82
1936	67	62	27	33	32	46
1937	77	86	90	83	82	70
1938	87	89	90	92	97	90
1939	80	82	90	87	84	54

¹Data from "Agricultural Outlook Reports," "Crop Reporter," "Weather, Crops and Markets," "Supplement to Crops and Markets," statistical section of "Yearbook of Agriculture" and "Crops and Markets," publications of the U. S. Department of Agriculture.

INDEX

	Page
Alfalfa—	
acreage, yield, production, 1919-39	266
prices, monthly, 1915-39	226
Annual average prices for major commodities—	
base periods, 1921-29 and 1920-29	253
Apples—	
prices and relatives of prices, monthly, 1910-39	194, 195, 253
production, price, farm value, 1919-38	255
Barley—	
acreage, yield, production, price, farm value, 1909-39	261
amount sold from farms, 1909-37	265
prices and relatives of prices, monthly, 1910-39	196, 197, 253
Beef cattle—	
prices and relatives of prices, monthly, 1910-39	228, 229, 253
production, 1924-38	281
Brome grass seed—	
production, yield, price, farm value, 1910-39	270
Buckwheat—	
acreage, yield, production, price, farm value, 1919-39	261
prices, monthly, 1933-39	226
Butter—	
prices, monthly, 1910-39	252
Butterfat—	
prices and relatives of prices, monthly, 1910-39	230, 231, 253
Cabbage for market—	
acreage, yield, production, price, farm value, 1918-38	255
Calves—	
production, 1924-38	281
see also Veal calves	
Cattle, all—	
number on farms, value per head, farm value, 1910-39	277, 278
see also Beef cattle, Calves, Milk cows, Veal calves	
Chickens—	
number on farms, value per head, farm value, 1924-39	281
prices and relatives of prices, monthly, 1910-39	232, 233, 253
Clover seed—	
acreage, yield, production, price, farm value, 1929-38	270
prices, monthly, 1932-39	227
Corn—	
acreage, yield, production, price, farm value, 1909-39	262
amount sold from farms, 1909-37	265
prices and relatives of prices, monthly, 1910-39	198, 199, 253
Cowpeas—	
acreage, yield, production, 1924-38	262
Cowry cows—	
see Milk cows	
Croch Irish potatoes for market—	
acreage, yield, production, price, farm value, 1918-38	256
Cucumbers—	
prices and relatives of prices, monthly, 1910-39	234, 235, 253
production, price, farm value, 1924-38	282
Farm real estate—	
index of value, 1912-39	283
Figs—	
production, 1919-39, price and farm value, 1930-38	256
Grapes—	
acreage, yield, production, price, farm value, 1909-39	269
prices and relatives of prices, monthly, 1910-39	200, 201, 253

Hay—Continued

	Page
alfalfa—	
acreage, yield, production, 1919-39	266
prices and relatives of prices, monthly, 1915-39	226
clover and timothy—	
acreage, yield, production, 1924-39	266
prices, monthly, 1915-39	227
grains cut for green hay—	
acreage, yield, production, 1919-38	267
lespedeza—	
acreage, yield, production, 1924-38	267
miscellaneous tame—	
acreage, yield, production, 1919-38	269
prairie hay—	
prices, monthly, 1927-39	227
sweet sorghums for forage and hay—	
acreage, yield, production, 1919-38	268
wild—	
acreage, yield, production, 1912-39	268
Hogs—	
number on farms, value per head, farm value, 1910-39	277, 278
prices and relatives of prices, monthly, 1910-39	236, 237, 253
production, 1924-38	281
Horses—	
number on farms, value per head, farm value, 1910-39	278, 279
prices and relatives of prices, monthly, 1910-39	238, 239, 253
Lambs—	
number on farms, value per head, farm value, 1910-39	278, 280
prices and relatives of prices, monthly, 1910-39	240, 241, 253
production, 1924-38	281
Land—	
index of value, 1912-39	283
Lespedeza—	
hay—see Hay	
seed—acreage, yield, production, price, farm value, 1929-38	271
Livestock numbers—	
see specific type	
Milk cows—	
number on farms, value per head, farm value, 1910-39	278, 279
prices and relatives of prices, monthly, 1910-39	242, 243, 253
Mules—	
number on farms, value per head, farm value, 1910-39	278, 280
prices and relatives of prices, monthly, 1910-39	244, 245, 253
Oats—	
acreage, yield, production, price, farm value, 1909-39	263
amount sold from farms, 1909-37	265
prices and relatives of prices, monthly, 1910-39	202, 203, 253
Onions for market—	
acreage, yield, production, price, farm value, 1918-38	257
Orchard grass seed—	
production, yield, price, farm value, 1910-39	271
Pasture—	
condition, monthly, 1914-39	283
Peaches—	
production, price, farm value, 1919-39	257
Pears—	
production, price, farm value, 1919-39	258
Potatoes—	
acreage, yield, production, price, farm value, 1909-39	258
prices and relatives of prices, monthly, 1910-39	204, 205, 253
see also Early Irish potatoes for market	

Thirty Years of Farm Prices and Production

287

	Page
acreage, yield, production, price, farm value, 1909-38	263
amount sold from farms, 1909-37	265
prices and relatives of prices, monthly, 1910-39	206, 207, 253
of specific type	
—	
number on farms, value per head, farm value, 1910-39	278, 280
prices and relatives of prices, monthly, 1910-39	246, 247, 253
production, 1924-38	281
(sorghum) sirup—	
acreage, yield, production, price, farm value, 1919-38	264
beans—	
acreage, yield, production, 1924-38	264
berries for market—	
acreage, yield, production, price, farm value, 1918-38	259
prices and relatives of prices, monthly, 1910-39	208, 209, 253
potatoes—	
acreage, yield, production, price, farm value, 1910-39	259
prices and relatives of prices, monthly, 1910-39	210, 211, 253
sorgho—	
type 22, (Eastern fire-cured)	
acreage, yield, production, price, farm value, 1919-39	273
prices and relatives of prices, monthly, 1914-38	212, 213, 253
production chart, 1919-39	272
type 23, (Western fire-cured)	
acreage, yield, production, price, farm value, 1919-39	273
prices and relatives of prices, monthly, 1914-38	214, 215, 253
production chart, 1919-39	272
type 24, (Henderson fire-cured)	
acreage, yield, production, price, farm value, 1919-39	274
prices and relatives of prices, monthly, 1914-38	216, 217, 253
production chart, 1919-39	272
type 31, (Burley)	
acreage, yield, production, price, farm value, 1919-39	274
prices and relatives of prices, monthly, 1909-38	218, 219, 253
production chart, 1919-39	272
type 35, (One Sucker)	
acreage, yield, production, price, farm value, 1919-39	275
prices and relatives of prices, monthly, 1914-38	220, 221, 253
production chart, 1919-39	272
type 36, (Green River)	
acreage, yield, production, price, farm value, 1919-39	275
prices and relatives of prices, monthly, 1914-38	222, 223, 253
production chart, 1919-39	272
toes for manufacture—	
acreage, yield, production, price, farm value, 1918-38	260
toes for market—	
acreage, yield, production, price, farm value, 1918-38	260
keys—	
number raised, value per head, farm value, 1929-38	282
prices, monthly, 1913-39	252
calves—	
prices and relatives of prices, monthly, 1910-39	248, 249, 253
—	
acreage, yield, production, price, farm value, 1909-39	265
amount sold from farms, 1909-37	265
prices and relatives of prices, monthly, 1910-39	224, 225, 253
—	
prices and relatives of prices, monthly, 1910-39	250, 251, 253

Kentucky Agricultural Experiment Station

University of Kentucky

BIOCHEMICAL AND SEROLOGICAL STUDIES OF MICROORGANISMS OF THE SALMONELLA CHOLERAЕ-SUIS GROUP

BULLETIN NO. 404



Lexington, Ky.

June, 1940

BIOCHEMICAL AND SEROLOGICAL STUDIES OF
MICROORGANISMS OF THE SALMONELLA
CHOLERAE-SUIS GROUP

By D. W. BRUNER and P. R. EDWARDS

The discovery of the "hog cholera bacillus" by Salmon and Smith (1885) constitutes the first recorded isolation of any of the large group of food-poisoning bacilli now included in the genus *Salmonella*. Altho it has been recognized for many years that *S. cholerae-suis* (*S. suipestifer*) is not the etiologic agent of hog cholera, the organism remains an important member of the paratyphoid group capable of producing disease in animals and man. Shortly after *S. cholerae-suis* was found numerous species of paratyphoid bacilli were isolated from a variety of diseases in man and the lower animals. These bacilli were so closely related that their differentiation could not be accomplished by the methods then in use. This condition inevitably resulted in the confusion of various types and in the early literature the terms *Bacillus paratyphosus B* and *Bacillus suipestifer* were applied indiscriminately to a variety of species. It was not until a group of British workers applied the agglutinin absorption test to the differentiation of paratyphoid bacilli that *S. cholerae-suis*, or *B. suipestifer* as it was then called, began to emerge from the confused mass of paratyphoid types as a distinct entity. O'Brien (1910), Bainbridge and O'Brien (1911) and Bainbridge (1912) found that *S. cholerae-suis* could be differentiated from *S. paratyphi B* and *S. typhi-murium* by agglutinin absorption. American investigators further clarified the position of *S. cholerae-suis* by correlating the serological and biochemical characteristics of the bacillus. Krumwiede and his coworkers (1916, 1916a, 1918) and Jordan and his associates (1917, 1917a) demonstrated that *S. cholerae-suis* differed from closely related types in its failure to ferment arabinose and inositol, its slight avidity for dulcitol and its failure to blacken lead acetate agar. Paratyphoid organisms that possessed the above biochemical peculiarities formed a well-defined serological type which was distinguishable from related species by the use of the agglutinin absorption test. Koser (1921) later demonstrated that bacilli of this type failed to attack trehalose.

It is significant that the cultures with which Krumwiede and Jordan worked were isolated in the United States. Shortly after their results were published Hirschfeld (1919) and MacAdam (1919) described bacilli isolated from infections in man in southeastern Europe and Asia Minor which were related to, but not identical with, *S. paratyphi B* and *S. typhi-murium*. Schuetze (1920) found that the organisms of MacAdam and of Hirschfeld belonged to the same serological type. Altho these organisms readily fermented arabinose and dulcitol and blackened lead acetate agar, Ten Broeck (1920) demonstrated that they were serologically identical with *S. cholerae-suis*. Andrewes and Neave (1921) investigated a number of cultures of the *S. cholerae-suis* group, some of which came from America and some from Europe. They found that the group could be divided into two serological types. The first was made up of American hog cholera strains, *S. paratyphi C* of Hirschfeld (1919) and *S. typhi-suis* of Glaesser (1909). The second type was composed of Western European strains of hog cholera bacilli (Kunzendort type) and the Voldagsen strains of Dammann and Stedefeder (1910). Type I was able to absorb agglutinins from serums derived from bacilli belonging either to type I or type II. Type II bacilli, on the contrary, were able to exhaust the agglutinins only from serums derived from bacilli of that type, but could not exhaust type I serum of agglutinins for the homologous strains.

The results of Andrewes and Neave were confirmed by White (1925, 1926) who made a careful study of the antigenic characteristics of the strains of the *S. cholerae-suis* group. By applying the observations of Andrewes (1922) concerning phase variation to this group he discovered that the organisms of type I of Andrewes and Neave were diphasic and possessed specific and nonspecific components. The strains of type II, on the contrary, were monophasic and occurred only in the nonspecific phase. Repeated attempts to isolate the specific phase from the latter cultures failed. These findings explained the one-sided absorptive relationship of the two types. White also investigated the biochemical behavior of the various strains and correlated it with their serological properties. His cultures fell into 5 types, as follows.

1. American cultures from swine.
2. Western European strains from man and swine.
3. Eastern European and Asiatic strains from man.

4. *S. typhi-suis* of Glaesser.

5. Voldagsen strains of Dammann and Stedefeder.

The distinguishing characteristics of these types as given in the literature are set forth in table 1. The work of White was in close agreement with the results obtained by Jordan and by Krumwiede and was amply confirmed by subsequent investigators. So well did the characteristics of the bacilli coincide with their geographical source that Kauffmann (1931) designated the first three groups of White as follows: 1. Typus-Suipestifer Amerika. 2. Typus-Suipestifer Kunzendorf. 3. Typus-Orient. In the report of the Salmonella Subcommittee (1934) the organisms were called *S. cholerae-suis*, *S. cholerae-suis* var. *kunzendorf* and *S. paratyphi* C, respectively. It is from the latter terms that the organisms are usually designated in Europe today.

Table 1. Characteristics of types within the *S. cholerae-suis* group.

Types	Fermentation of				Production of hydrogen sulfide	Phases normally present
	Arabinose	Dulcitol	Mannitol	Trehalose		
American	-	±	+	-	-	Specific and nonspecific
Western European	-	±	+	-	+	Nonspecific
Eastern European and Asiatic	+	+	+	+	+	Specific and nonspecific
<i>S. typhi-suis</i>	+	+	-	+	+	Specific and nonspecific
Voldagsen	+	+	-	+	+	Nonspecific

In the work cited above the cultures of American origin were isolated previous to 1920 and many of those studied by European workers were derived from the collection of Dr. Jordan. Little work has been done with cultures isolated in the United States since 1920, and almost none of those described were subject to the tests necessary for exact typing. The examination of a few cultures recently isolated by the writers did not support the view that practically all strains of the *S. cholerae-suis* group isolated from hogs in the United States were diphasic cultures which failed to produce hydrogen sul-

fide. Since these findings were at variance with the results of earlier investigators, it was decided to collect a number of recently isolated strains and type them. A small number of the older cultures were included in the study and a few European strains were used for comparison.

MATERIALS AND METHODS

In all, 162 cultures were examined. All the strains possessed the morphological, cultural and biochemical characteristics of the genus *Salmonella*. In addition all were motile bacilli which produced acid and gas from xylose and mannitol and failed to attack inositol. For convenience the organisms may be divided into type strains used for comparison, and more or less recently isolated strains whose identity it was wished to establish.

The type cultures employed were as follows:

S. cholerae-suis.

250, 350 — strains of hog cholera bacilli originally isolated by Dr. Theobald Smith.

171 — from National Collection of Type Cultures, London. Original from the collection of Dr. E. O. Jordan.

1348 — type culture from Dr. F. Kauffmann.

S. cholerae-suis var. *kunzendorf*.

1713, 309 — from National Collection of Type Cultures, London typed by White (1926).

1350, 5210 — type cultures from Dr. F. Kauffmann.

S. paratyphi C.

90 — from National Collection of Type Cultures, London. Original strain of Hirschfeld.

319 — from New York City Department of Health Isolates in Asia Minor.

S. typhi-suis.

348 — from the National Collection of Type Cultures, London. Original from Reichsgesundheitsamt, Berlin. Poppe strain.

S. typhi-suis var. *voldagsen*.

346 — from the National Collection of Type Cultures, London. Original from Reichsgesundheitsamt, Berlin. Dammann strain.

Among the cultures the identity of which was unknown were 124 strains from swine. Most of these strains were isolated in Ca

oma, Kentucky, Indiana, Illinois, Kansas and Minnesota. The eggs from which they were derived were affected with a variety of pathological conditions. The diseases occurring most frequently in this group were hog cholera, necrotic enteritis and pneumonia. Inasmuch as no correlation could be established between the type of organism and the disease with which it was associated, no attempt will be made to list separately the organisms from different diseases. Seventeen cultures were isolated from foxes. All the latter strains were obtained from other laboratories and little is known concerning the conditions from which they were isolated. Undoubtedly, some of them were associated with virus encephalitis. Four cultures were isolated from cases of food poisoning in man. Two of these infections terminated fatally. Two cultures were isolated from cattle and one each from a dog, a chicken and a canary.

The organisms were tested for hydrogen sulfide production by suspending papers impregnated with neutral lead acetate over cultures in 2-percent peptone water. The tubes were incubated for 2 weeks before being discarded. Fermentation tests were conducted in nutrient broth containing 1 percent Andrade's indicator and 0.5 percent of the fermentable substances. Fermentation tests were incubated at 37 C. for three weeks before being discarded.

The presence of specific and nonspecific phases in the cultures was determined by slide agglutination with suitably diluted specific *S. cholerae-suis* and *S. cholerae-suis* var. *kunzendorf* antisera. In instances in which there was any doubt as to the results of the tests, and in those cases in which the serological results did not confirm the biochemical tests, expanded agglutination tests were carried out using formalinized broth cultures as antigens. The somatic antigens were examined by the method of Kauffmann (1937).

After the cultures were typed the monophasic nonspecific cultures were examined by a modification of the method of Wassén (1935) to determine the presence of suppressed specific phases in *S. cholerae-suis* var. *kunzendorf*. In this method semi-solid agar of the following composition was employed.

Bactopectone	10.0 gm.
Meat extract	3.0 gm.
Sodium chloride	5.0 gm.
Bactoagar	4.0 gm.
Bactogelatin	80.0 gm.
Water	1000.0 cc.

The reaction was adjusted to pH 7.4 and the medium dispensed into 13x100 mm. tubes in amounts of 4.0 cc. Sterilization was accomplished by autoclaving at 15 pounds pressure for 20 minutes. The melted agar was cooled to 40 C. and sufficient serum derived from *S. cholerae-suis* var. *kunzendorf* added aseptically to make final serum concentration of 1 to 4000. The titre of the antiserum for the homologous strain was 1 to 20,000. The serum employed in the tests was sterilized by the addition of 0.5 percent CHCl_3 at the time it was separated from the blood clot. This amount of CHCl_3 did not interfere with growth or motility of the bacilli when the serum was diluted for the tests. The solidified agar was inoculated with a loopful of the culture to be tested by stabbing at one side of the tube. The antiserum immobilized the nonspecific phase of the bacillus so that growth occurred as a thin line at the site of inoculation. Appearance of the specific phase was accompanied by the migration of the organisms thru the medium with the extension of filmy bulbs from the line of stab. In some instances these bulbs appeared on the first transfer in immune serum agar; other strains produced them only after two or three transfers. Transfers from the bulbous projections spread rapidly when transferred to other tubes of the same medium, so that the whole tube was turbid after overnight incubation. Broth cultures inoculated with this spreading growth were used as antigen in agglutination tests with specific and nonspecific *S. cholerae-suis* antiserum.

Before the results of the tests are summarized it should be emphasized that the differentiation of the cultures was remarkably clear cut. In the tests for hydrogen sulfide production the lead acetate papers were either blackened within 24 hours or remained unchanged thruout the period of observation. Furthermore, those cultures which produced hydrogen sulfide caused very pronounced blackening of the test papers. No delayed positive or doubtful tests were encountered. In addition the tests for hydrogen sulfide production correlated well with the examinations for the presence of the specific phase in the cultures. In only three instances was any divergence from the pattern established by other workers noted. This divergence occurred in three cultures which produced hydrogen sulfide, yet were diphasic.

None of the cultures fermented arabinose or trehalose. Dulcitol was fermented by a number of cultures. As emphasized by Krum

de, Kohn and Valentine (1918), the action of this group of *Salmonella* on dulcitol is quite irregular and only negative results or delayed reactions are of diagnostic importance. None of the cultures studied here fermented the substance rapidly and most of these strains which attacked it caused no perceptible production of acid before the fifth or sixth day of incubation. The fermentation of dulcitol by the organisms seems to have little significance since cultures from the same outbreak of infection vary in their ability to produce acid and gas from this substance.

The results of the examination of the cultures are presented in Table 2. The type cultures gave reactions identical with those gen-

Table 2. Characteristics of cultures studied.

	Number of cultures	Production of hydrogen sulfide	Fermentation of			Diphasic	Monophasic, nonspecific
			Arabinose	Dulcitol	Trehalose		
<i>Salmonella</i> Cultures							
<i>cholera-suis</i>	4	—	—	—	—	4	0
<i>cholerae-suis</i> var. <i>kunzendorf</i>	4	+	—	2+	—	0	4
<i>paratyphi C</i>	2	+	+	+	+	2	0
<i>typhi-suis</i>	1	—	+	+	+	1	0
<i>typhis-suis</i> var. <i>voldagsen</i>	1	—	+	+	+	0	1
Identified Cultures							
Wine	10	—	—	1+	—	10	0
	111	+	—	9—	—	0	111
	3	+	—	42+	—	3	0
Oxes	2	—	—	69—	—	2	0
	15	+	—	2+	—	0	15
	1	—	—	1—	—	1	0
Cows	1	+	—	9—	—	0	1
Dog	1	+	—	—	—	0	1
Chicken	1	—	—	—	—	1	0
Canary	1	+	—	—	—	0	1
Man	1	—	—	—	—	1	0
	3	+	—	1+	—	0	3
				2—	—		

erally attributed to members of their respective species with the exception of the fermentation of mannitol by *S. typhi-suis* and *typhi-suis* var. *voldagsen*. White (1926) noted that these two types did not attack mannitol. He studied two cultures of each species. Most workers since that time have agreed that mannitol was not attacked by these bacilli. In the present work the supposedly authentic stock cultures of the Glaesser and Voldagsen types attacked mannitol readily and produced demonstrable acid from the substance after 24 hours incubation. These tests were repeated several times and each time fermentation was observed. Since no other cultures of these species were readily available the question was not investigated further. These two cultures were included in White's collection and it is possible that they have acquired the property of fermenting mannitol after prolonged artificial culture. That the mannitol used in the tests was not hydrolyzed is indicated by the failure of *Streptococcus equi* to ferment it. Glaesser and Voldagsen's bacilli are found quite rarely in Europe and have not been recognized among cultures isolated in the United States. They are easily distinguished from other members of the *S. cholerae-suis* group by their delicate growth on artificial mediums.

The unidentified cultures were divisible into three types: *S. cholerae-suis*, *S. cholerae-suis* var. *kunzensdorf* and diphasic strains which exhibited the biochemical characters of the Kunzensdorf variety. Only 15 of the 150 unidentified cultures were classified as *S. cholerae-suis*. These cultures failed to produce hydrogen sulfide and were diphasic. Like the other cultures they failed to ferment arabinose and trehalose and behaved irregularly in dulcitol broth. Ten of the *S. cholerae-suis* cultures were isolated from swine, two from foxes, one from a cow, one from a chicken and one from man. The great majority of the untyped cultures were typical representatives of the Kunzensdorf variety. Of the 150 cultures, 132 belonged to this type. Of these, 111 were derived from swine, 15 from foxes, one from a cow, one from a dog, one from a canary, and one from man.

In addition three cultures from swine, which had the cultural characters of the Kunzensdorf variety, were diphasic. Kristensen and Bojlen (1936) noted one such strain among twenty Kunzensdorf cultures which they studied. These three strains form a connecting link between the hydrogen-sulfide-negative, diphasic *S. cho*

cholerae-suis and the hydrogen-sulfide-positive, monophasic Kunzendorf type.

Levine and Frisch (1935) demonstrated that certain cultures of the *S. cholerae-suis* group differed in their behavior toward bacteriophage. They were able to show that differences in phage susceptibility could be correlated with differences in somatic antigens. Following this work, Kauffmann (1937) examined in detail the heat-stable antigens of a number of cultures. He confirmed the findings of Levine and Frisch. Previously the somatic antigens of the bacilli had been expressed by the symbols VI-VII of the Haffman-White schema. Kauffmann found that factor VI was divisible into 2 fractions which he denoted VI₁ and VI₂. *S. paratyphi C* and *S. typhi-suis* possessed both antigens. The cultures of *S. cholerae-suis* which he examined contained only VI₁, as did also the majority of the Kunzendorf strains. Two cultures of the Kunzendorf type contained VI₂ but lacked VI₁. In the present study 79 cultures were examined for the presence of antigens VI₁ and VI₂. All the strains of *S. cholera-suis* and all but 3 cultures of Kunzendorf strains examined contained VI₁ but not VI₂. These 3 Kunzendorf strains contained VI₂ but lacked VI₁. Two of the latter strains were from hogs, the other from a fox. The fractions present in the somatic antigens of the bacilli could not be correlated with the animal host or type of disease from which they were derived.

Gard (1937) stated that he was able to isolate specific phases from Kunzendorf strains by the technic of Wassén (1935). Herrmann (1939) was unable to isolate specific phases from the bacilli, using soft agar plates containing nonspecific agglutinating serums. In the present study 79 of the monophasic-nonspecific cultures were studied by the method of Wassén (1935). By cultivation in semi-solid agar containing antiserum for the Kunzendorf type it was possible to isolate a specific phase from every culture tested. These included all the stock cultures of *S. cholerae-suis* var. *kunzendorf* and *S. typhi-suis* var. *voldagsen*. The specific phases were found in the type cultures which were isolated in western Europe as well as in cultures of American origin. The specific phases thus obtained were identical with the specific components of the naturally diphasic *S. cholerae-suis* and were able to absorb completely the agglutinins in specific *S. cholerae-suis* antiserum.

DISCUSSION

There has been a marked change in the type of organisms in the *S. cholerae-suis* group isolated from domestic animals in the United States. Whereas diphasic, hydrogen-sulfide-negative strains were found almost exclusively previous to 1920, today the monophasic, hydrogen-sulfide-positive type predominates. In the collection studied the Kunzendorf variety composed 90 percent of the cultures. The bacilli in the collection were not isolated in a single locality but were derived from animals in a number of different states. Thus the relative frequency of the occurrence of the type among the cultures studied should be a fairly accurate index of the relative frequency of these types in the country as a whole. Jordan found that his cultures which resembled *S. cholerae-suis* in their fermentative and serological properties failed to produce hydrogen sulfide. Krumwiede, Kohn and Valentine (1918) stated that practically all their cultures of *S. cholerae-suis* failed to blacken lead acetate. The few exceptions were very old stock strains. Presence of the specific phase was not determined in the cultures of Jordan and of Krumwiede. However, the failure of the bacilli to blacken lead acetate and the fact that White (1926) later examined many of the cultures and found them diphasic, is rather conclusive evidence that the Kunzendorf type was found very infrequently in the United States at that period. The only Kunzendorf strain of American origin typed by White was isolated from man. The reason for and the significance of this change in type is not clear. The predominance of the Kunzendorf variety in the United States and the repeated isolation of diphasic cultures in Europe by Tesdal (1938) and others render completely invalid the terms "American" and "Western European" as they have been used in connection with this group of bacilli.

The recognition of three strains which were diphasic yet produced hydrogen sulfide vigorously is of especial interest. As stated previously these cultures form a connecting link between *S. cholerae-suis* and the Kunzendorf variety and offer evidence that the latter type may occur naturally in the diphasic state. Therefore, it is not surprising that the specific phase may be isolated from these strains. The ease with which specific components were isolated by the Waksén technic varied with different strains. Some cultures yielded the suppressed phase after only one or two transfers in agar containing

specific serum. It was isolated from other strains only after repeated transfers over a period of several weeks. On the whole it is difficult to demonstrate the specific phase in Kunzendorf cultures than in any of the other so-called monophasic nonspecific *Salmonella* types.

The recognition of specific phases in *S. cholerae-suis* var. *kunzendorf* leaves only the production of hydrogen sulfide to distinguish the variety from *S. cholerae-suis*. The continued separation of the two types on the basis of hydrogen sulfide production is not justified since this difference is a quantitative and not a qualitative one. While it is stated throughout the present report that *S. cholerae-suis* does not produce hydrogen sulfide, it should be understood that by this statement is meant that the bacilli failed to blacken lead acetate papers suspended over peptone water cultures. That they actually produce hydrogen sulfide may be demonstrated by the cultivation of the bacilli on bismuth sulfite agar, on which medium they produce black colonies. Hunter and Crecelius (1938) demonstrated that the results obtained in testing for hydrogen sulfide production varied with the tests employed for the detection of the substance. But the method employed here for the detection of hydrogen sulfide production is more delicate than the lead acetate agar or ferric chloride gelatin usually used in bacteriological work is evidenced by the blackening of lead acetate papers by cultures of *S. paratyphi* which give negative results in lead acetate agar and ferric chloride gelatin. It is the opinion of the writers that all *Salmonella* cultures produce a certain amount of hydrogen sulfide.

S. typhi-suis and *S. typhi-suis* var. *voldagsen* were not found among the cultures isolated in the United States. However, two cultures classified as *S. cholerae-suis* var. *kunzendorf* deserve special mention. These two cultures were isolated from hogs in California and were forwarded to the writers by Dr. W. R. Hinshaw. While the cultures possessed the biochemical characteristics of typical Kunzendorf strains, they produced a delicate growth on the surface of infusion agar that closely resembled the growth of Glaesser Voldagsen bacilli. In this respect they were quite different from the remainder of the Kunzendorf cultures in the collection. No other cultures resembling the two California strains was noted in the literature. They probably represent a link between Kunzendorf and Voldagsen varieties.

The appearance of microorganisms of the *S. cholerae-suis* group in animals other than swine is important. Not only does it indicate that other animals may be carriers of the bacilli and convey the infection to swine but it also demonstrates the importance of not allowing animals of other species to come in contact with infected hogs. Infection of man with bacilli of this group is not uncommon and many references to their occurrence in human infections may be found. On the contrary little is known concerning the occurrence of *S. cholerae-suis* in animals other than swine. Tesdal (1938) reported the isolation of *S. cholerae-suis* and *S. cholerae suis* var. *kunzendorf* from foxes and *S. cholerae-suis* var. *kunzendorf* from dogs and chickens. Hippmann (1938) found the organisms in a cow and Becker (1939) isolated the bacilli from cows and horses.

In the present work, bacilli of the *S. cholerae-suis* group were found more frequently in foxes than in any animal species other than swine. The writers examined 42 *Salmonella* strains isolated from foxes and found that cultures of the *S. cholerae-suis* group occurred more frequently than any other *Salmonella* type. The two strains from cattle were received from Dr. S. J. Schilling. One was isolated from the kidney of a cow, the other from the liver of a calf that died 48 hours after birth. The culture from a chicken was received from Dr. M. W. Emmel. Nothing is known concerning the circumstances of its isolation. The culture from a canary was received from Dr. L. J. Goss. The bird from which the culture was isolated was one of a flock of 160 individuals of which 100 died. None of the other birds which died with similar symptoms were presented for postmortem examination.

While the organisms of the *S. cholerae-suis* group are the predominant *Salmonellas* found in hogs they are by no means the only types found in these animals. In a survey of salmonellosis of domestic animals the following *Salmonella* species were found in hogs: *S. paratyphi B*, *S. typhi-murium*, *S. derby*, *S. bareilly*, *S. newport*, *S. anatum*, *S. lexington*, *S. new brunswick* and *S. wichita*.

CONCLUSIONS

1. The examination of a number of cultures of the *S. cholerae-suis* group demonstrated that the Kunzendorf variety is the predominant type among these bacilli in the United States. *S. cholerae-suis*, which formerly predominated, is now found only occasionally.

2. By the use of the Wassén technic it was possible to isolate

Specific components from all the Kunzendorf strains examined. Three cultures of the Kunzendorf type were found to occur naturally in the diphasic state.

3. *S. typhi-suis*, *S. typhi-suis* var. *voldagsen* and *S. paratyphi* C were not found among cultures isolated in the United States.

4. Biochemical tests were of great value in identifying the bacteria. The failure of the cultures to ferment arabinose, trehalose and inositol served to distinguish them from other *Salmonella* species.

5. Microorganisms of the *S. cholerae-suis* group were found not only in hogs but in man, foxes, cattle, dogs, chickens and canaries.

6. In addition to the *S. cholerae-suis* group numerous other *Salmonella* types occur in hogs.

REFERENCES

- Andrewes, F. W. 1922 J. Path. and Bact., 25, 505.
 Andrewes, F. W. and Neave, S. 1921 Brit. J. Exp. Path., 2, 157.
 Bainbridge, F. A. 1912 Lancet, i, 705.
 Bainbridge, F. A. and O'Brien, R. A. 1911 J. Hyg., 11, 68.
 Becker, 139 Ztschr. f. Fleisch-u. Milchhyg., 49, 163.
 Dammann and Stedefeder. 1910 Arch. f. wiss. u. prakt. Tierheilk., 36, 432.
 Gard, S. 1937 Ztschr. f. Hyg., 120, 59.
 Glaesser, K. 1909 Deut. tieraertzl. Wochenschr., 77, 513 and 529.
 Herrmann, W. 1939 Zbt. f. Bakt., Abt., I, Orig., 143, 207.
 Hippmann, W. 1938 Ztschr. f. Fleisch-u. Milchhyg. 49, 45.
 Hirschfeld, L. 1919 Lancet, i, 296.
 Hunter, C. A. and Crecelius, H. G. 1938 J. Bact., 35, 185.
 Jordan, E. O. 1917 J. Inf. Dis., 20, 457.
 Jordan, E. O., and Victorson, R. 1917a J. Inf. Dis., 21, 554.
 Kauffmann, F. 1931 Zbt. f. d. ges. Hyg., 25, 273.
 1937 Ztschr. f. Hyg., 120, 177.
 Koser, S. A. 1921 J. Inf. Dis., 29, 67.
 Kristensen, M., and Bojlen, K. 1936 Zbt. f. Bakt., Abt. I, Orig., 136, 294.
 Krumwiede, C., Pratt, J. S., and Kohn, L. A.
 1916 J. Med. Res., 34, 335.
 1916a J. Med. Res., 35, 357.
 Krumwiede, C., Kohn, L. A., and Valentine, E. 1918 J. Med. Res., 38, 89.
 Levine, P., and Frisch, A. W. 1935 Proc. Soc. Exp. Biol. and Med., 32, 883.
 MacAdam, W. 1919 Lancet, ii, 189.
 O'Brien, R. A. 1910 J. Hyg., 10, 231.
 Salmon, D. E. and Smith, T. 1885 Second Ann. Rept. U. S. Bur. Anim. Ind., 184.
 Salmonella Subcommittee 1934 J. Hyg., 34, 333.
 Schuetze, H. 1920 Lancet, ii, 93.
 Ten Broeck, C. 1920 J. Exp. Med., 32, 33.
 Tesdal, M. 1938 Die Salmonellagruppe. Presa Buna, Jassy.
 Wassen, A. 1935 Bull. mensuel de l'Office Internatl. d'Hyg. publ., 27, 1.
 White, P. B. 1925 Med. Res. Counc. Gt. Brit., Spec. Rept. Ser. No. 91.
 1926 Med. Res. Counc. Gt. Brit., Spec. Rept. Ser. No. 103.

Kentucky Agricultural Experiment Station

University of Kentucky

VARIATIONS IN FARM INCOME AND FAMILY LIVING IN ROBERTSON COUNTY

BULLETIN NO. 405



Lexington, Kentucky

June, 1940

(305)

CONTENTS

Character of the area	P 3
Farm receipts, expenses and family living in 1935 and 1937	3
Family living furnished by farm	3
Farm expenses in 1935 and 1937	3
Labor income of farm operators	3
Relation of size of business to labor income	3
Relation of number of livestock to labor income	3
Livestock products sold per farm	3
Relation of crop acreage and yield to labor income	3
Crops grown	3
Crop yields	3
Relation of tobacco yield to labor income	3
Relation of weather conditions to labor income	3
Summary	3
Tabulated data (Appendix)	3

VARIATIONS IN FARM INCOME AND FAMILY LIVING IN ROBERTSON COUNTY

By JOHN H. BONDURANT and MAX M. THARP*

The purpose of this bulletin is to present an analysis of the farming experiences of a group of representative farmers in Robertson County, in order to provide a basis for farmers, on similar farms, to improve their methods of farming.

The information for this study was obtained from farmers in the central and northern areas of the county. A complete itemized record of all receipts and expenses was obtained from each farmer by personal interviews. The records included the experiences of 152 farmers for the year 1935 and 61 of the same farmers for the year 1937. In addition to the financial information, data on crop and livestock production and farm practices were obtained. The Soil Conservation Service provided detailed maps showing the type of soil, percent of slope, and estimated amount of erosion for each of the 61 farms. The farms visited were selected by choosing every third or fourth name from the listing sheets of the Agricultural Adjustment Program in the county.

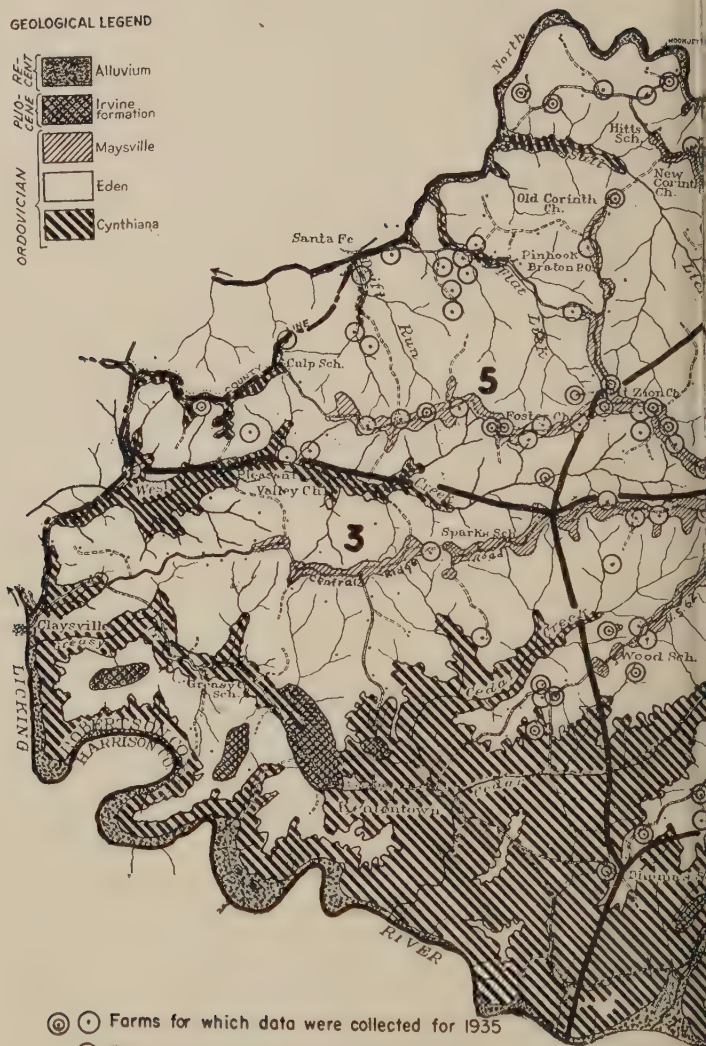
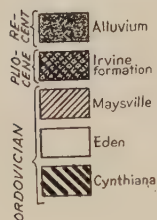
CHARACTER OF THE AREA

Robertson County lies in the northern section of the Bluegrass limestone hill region of Kentucky. The farms studied are in the northern section of the Eden Shale Formation. The topography, the soil in general and the type-of-farming in the Eden Shale portion of Robertson County are fairly representative of the Bluegrass hill region which is classified as type-of-farming sub-area 3b¹. There is considerable rough, steep, and stony land in this area. The region is characterized by deep, v-shaped valleys and narrow ridges, and there is very little bottom land along the streams. The soil is derived largely from calcareous shales and thin limestone, and in general is not so productive as most of the other soils of the Bluegrass

* Acknowledgements: W. L. Rouse supervised the field work and E. J. Nesius, E. F. Daniel and R. M. Sandefur served as field assistants in obtaining the data for the 152 farms, for the year 1935.

¹ Poundstone, Bruce and Roth, Walter J., Types of Farming in Kentucky, Kentucky Agricultural Experiment Station Bulletin No. 357, June, 1935.

GEOLOGICAL LEGEND



⊙ Farms for which data were collected for 1935

⊙ Farms mapped in 1936 and from which data were collected for 1937

Numbers refer to five Magisterial Districts (1, 2, 3, 4, 5)

SCALE: 1 INCH = 1 MILE

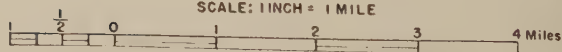




FIGURE 1. Geologic map of Robertson County.

Region. Limestone fragments are scattered on most of the slopes and interfere with tillage unless removed. The soil washes badly on the slopes when in cultivation and at other times when it is not well protected with vegetation. On most of the farms studied a considerable proportion of the top soil has been eroded.

More than three-fourths of the soil on the 61 farms for which soil maps were made was classed as Eden Clay Loam by the Soil Conservation Service. This soil is derived principally from the Eden geologic formation (figure 1). The parent material of this soil is high in calcium and somewhat phosphatic thus making the soil rather fertile. Having been derived from shale, limestone, and some sandstone, there is considerable diversity in the character of this soil. It is generally basic or neutral and does not need ground limestone to grow alfalfa or other legumes successfully. Also it contains a large reserve of potassium. Most of the Eden Clay Loam has a very steep topography and is severely eroded where it has been used for cultivated crops.

The soil that caps most of the ridges is commonly called "ashy land" by the farmers in the region because of its ashy color and texture. This soil is derived largely from the Maysville geologic formation. It has a lower average slope than the Eden series, and for that reason is less severely eroded. However, when it extends far down the ridge, erosion is severe. In contrast with the Eden Clay Loam soil this "ashy land" is strongly acid and must be limed to grow alfalfa or other legumes successfully. However, many farmers reported higher than average production of good Burley tobacco on this "ashy" soil.

Because of the small amount of relatively level land available for cultivation on most of the farms studied, a high proportion of the steep land is regularly used for cultivated crops and this presents one of the chief difficulties in the control of erosion in this area. In general, the farms of the area are small, usually with well-kept but modest buildings. Most of them are one-family farms. There are fewer tenants on the farms in this region than in most of the other parts of the Bluegrass Region.

All-weather automobile roads are accessible to most of the farms in the county. Markets at Cynthiana and Maysville are convenient for the sale of tobacco. Lambs and veal calves are marketed in

Paris, Cynthiana and Maysville. Cincinnati, about 60 miles from Mt. Olivet, the county seat, serves as the principal terminal market for livestock, wool, poultry, eggs and cream. These products are usually assembled at Mt. Olivet before being trucked to the terminal markets.

**FARM RECEIPTS, FARM EXPENSES AND FAMILY
LIVING IN 1935 AND 1937**

Farm receipts and expenses and family living data were obtained from 152 farmers in 1935 and complete data as to soil type, amount of erosion, percent of slope, and farm practices, on 61 of these farms. The financial, acreage and other data for the 152 farm corresponded very closely with those for the smaller group of 61 farms. In summarizing the data for the 1935 analysis, four of the 61 farms were omitted because, in that year, a very large proportion of their gross receipts came from sources other than farming. In most of the analyses in this bulletin, 61 farms were used for the year, 1937, and 57 of these farms were included for the year, 1935.

In 1937 the 61 farms had total receipts averaging \$1,284 per farm². Receipts from tobacco were 58 percent of the total; other crops, 6 percent; cattle and dairy products, 12 percent, and other livestock, 12 percent. Agricultural Conservation Payments and government phosphate accounted for 6 percent; outside labor, 3 percent; miscellaneous receipts 1 percent, and net increases in feeds and supplies, 2 percent (table 1).

The total receipts on the 61 farms, in 1937, ranged from \$198 to \$2,258. Twenty percent of the farms had total receipts under \$600; 30 percent, from \$600 to \$1,099; 33 percent, from \$1,100 to \$1,599, and 26 percent above \$1,600. Only one of the 61 farmers had receipts above \$3,000.

The total receipts on 57 of these same farms, in 1935, averaged \$1,335. Forty-seven percent had receipts totaling less than \$600, 38 percent from \$600 to \$1,099 and only 15 percent had receipts above \$1,100. The most striking difference in farm receipts was in the income from tobacco. In 1935 tobacco receipts were \$224 as contrasted with \$739 in 1937, a difference of \$515 per farm. In 1935 these farms grew 2.9 acres of tobacco as compared with 4.3 acres in 1937. The increase in tobacco receipts was due mainly to higher yields and

². Total receipts also include increases in inventories and the value of crops given share.

Table 1. Average farm receipts and net increases, Robertson County in 1937 and 1935.¹

Receipt items	1937 61 farms	1935 57 farms
	dollars	dollars
Tobacco	739	224
Wheat	37	17
Corn and fodder	28	29
Hay	14	10
Other crops	3	3
Crop receipts	821	283
Cattle and dairy products	150	168
Sheep and wool	92	73
Poultry and eggs	69	85
Hogs	(-2) ²	1
Horses and mules	(-3) ²	(-2) ²
Livestock receipts and net increases	306	327
A.C.P. payments and Government phosphate	79	68
Labor off the farm	33	37
Miscellaneous receipts	17	28
Net increase in inventory of feeds and supplies	28	(-6) ²
Other receipts	157	12
Total receipts and net increases	1,284	737

¹ Net increase is sales plus ending inventory minus purchases and beginning inventory.

² Net decrease.

price rather than to the increased acreage. The average yield in 1937 was 789 pounds per acre as compared with 588 pounds in 1935. The average price per pound of tobacco received in 1937 was 21.1 cents as compared with 13.2 cents in 1935, a difference of 8.5 cents per pound.

In 1935 the average Burley tobacco price for the Maysville and Cynthiana markets was \$17.52 per 100 pounds. This was \$4.32 more than the average price received by the 57 farmers whose records were summarized for this report. In 1937 the average price for the two markets was \$22.04 per 100 pounds which was only 34 cents more than the average received by the 61 farmers in the study.

The tobacco acreage was 48 percent greater, the yield 34 percent greater, and the price received 64 percent greater in 1937 than in 1935, on the same group of farms. The increase in acreage of tobacco, however, at its 1937 yield and price, accounted for approximately

40 of the difference in tobacco receipts between the two years and the yield and price made up \$275 of the remaining difference. In contrast with the wide fluctuation in receipts from tobacco, the returns from livestock showed very little change for the two years. This emphasizes the importance of a proper balance in the enterprises on these farms, since such year-to-year fluctuations in receipts are characteristic of farms that are highly specialized in the production of a single cash crop such as tobacco.

Family Living Furnished by the Farm. Receipts of this kind make up a considerable part of the annual returns to farmers in the area studied. The average quantities and values of these items, at farm prices, are stated in table 2.

Table 2. Family living furnished by the farm, Robertson County, 1937 and 1935.

Item	1937 Average for 61 Farms		1935 Average for 57 Farms	
	Quantity	dollars	Quantity	dollars
Garden and truck	0.4 acre	43	0.7 acre	48
Pork	636.0 lbs.	51	681.0 lbs.	67
Chickens	47.0 head	14	62.0 head	21
Milk	321.0 gal.	39	324.0 gal.	39
Eggs	103.0 doz.	19	103.0 doz.	15
Total food		166		190
Fuel (wood)	7.0 cords	11	10.0 cords	16
Use of house (10% of inventory value)		136		141
Total value of family living		313		347

On an average, these farms furnished total perquisites to the families living on them valued at \$313 in 1937 and \$347 in 1935. Food furnished by the farm made up over 50 percent of the total value. The average family used 0.4 of an acre of their land for garden and truck which returned products valued at \$43 per farm. In addition to garden and truck the average operator's family consumed 636 pounds of pork, 47 chickens, 103 dozen eggs and 321 gallons of milk produced on their farms for the year 1937. The total food furnished by the farm was valued at \$166 per farm in 1937 and \$190 in 1935. The farms also furnished an average of seven cords of wood per farm in 1937 and ten cords in 1935. The value for the use of the house was computed by taking ten percent of the beginning inventory value. This amounted to \$136 per farm in 1937 and \$141 in 1935.

Farm Expenses. Total farm expenses per farm amounted to an average of \$531 in 1937 and \$418 in 1935. Current expenses made up 76 percent of the total in 1937 and 62 percent in 1935. Appendix, table 10, gives a detailed summary of total expenses for the farms for 1937 and 1935. In 1937 the largest single item in current expenses was cropper labor which included the value of the crop given as a share by the operator to the cropper, for raising the crop. This figure also includes Agricultural Conservation payments received by the cropper. The cropper labor item amounted to \$141 per farm, or 36 percent of the current expense, in 1937, and if hired labor cost is added to this figure the total labor expense, other than the labor of the operator and his family, amounted to \$178 per farm or 44 percent of the current expenses. In 1935, cropper labor cost made up only 12 percent of the total current expense. This was due mainly to the extremely low receipts from tobacco for that year. Hired labor expense was also less for 1935. Taxes averaged \$47 per farm in 1937 and \$50 in 1935. The higher expenses for labor, fertilizer and limestone, and seeds and plants, for 1937, account for most of the difference in current expenses for the two years. In 1937 these farmers spent an average of \$22 per farm for fertilizer and limestone, but in 1935 they spent an average of only \$1 per farm. The amount spent for seeds and plants in 1937 was about 30 percent more than in 1935, amounting to \$29 and \$19, respectively, for the two years. The increased use of fertilizer, limestone, grass and legume seeds is indicative of an increased interest in better land use by farmers of this area. Depreciation, the value of unpaid family labor and net decreases in inventories added to current expenses make up the total farm expenses.

LABOR INCOME OF FARM OPERATORS⁴

The labor incomes earned by the farmers in this study varied widely for both 1937 and 1935. A farm business summary showing averages for the two years is presented in the Appendix, table 13. Labor incomes for these farmers averaged \$451 in 1937 and \$17 in 1935. Ranging from a negative \$314 to \$1,903 there was a difference

3. The value of the cropper's share was also included as a receipt and thus balanced out in figuring net farm income.

4. Labor income is farm income less interest on capital invested in the farm business. It is what the farmer receives for his labor and supervision of the farm business in addition to the use of a dwelling and to that part of the family living furnished by the farm.

the labor income between the two extremes of \$2,217, in 1937. About 15 percent of these farmers in 1937 had negative labor incomes, and about 33 percent had labor incomes of less than \$200. With a range from a negative labor income of \$435 to a positive labor income of \$835, about 54 percent of these farmers had negative labor incomes in 1935, and about 82 percent earned labor incomes of less than \$200.

Increased receipts in 1937 rather than lower expenses were responsible, in large part, for the difference in labor incomes for the two years. As has been shown, the receipts from tobacco alone averaged \$515 more per farm in 1937, and the total farm receipts were \$2,284 compared with \$735 in 1935, altho expenses increased only \$113, or from \$418 in 1935 to \$531 in 1937.

The question naturally arises as to the causes of the wide variations in receipts and labor incomes on these farms, in the same year and from one year to another. There are no doubt many reasons for these differences. Some of them probably arise from the natural differences in the land on different farms, or the way the farms have been used in the past, the plan of operation by the individual operator for the year, weather conditions, the acreage, investment in the farm, the size and kinds of crop and livestock enterprises, the equipment used and the tillage practices of the operator. In the following sections of this bulletin important factors which influenced the wide differences in labor incomes are described and analyzed.

RELATION OF SIZE OF BUSINESS TO LABOR INCOME

Generally the size of business is an important factor in determining the labor income of a farm operator. A business of adequate size offers a better chance to use the available labor efficiently than does a small business. However, if a large business is conducted inefficiently or price and production conditions are adverse, it is likely to show a greater loss than a smaller business conducted under the same conditions. There are several ways of measuring the size of a farm business, but on the farms in this study the productive man-work units⁵ probably is the best measure. This measure takes into consideration the acreage of each crop and the number of livestock on the farms and it also makes an allowance for each kind of crop and class of livestock. The total acres operated, in this area, gives

5. A productive man-work unit is the average amount of work accomplished by one man in 10 hours spent directly in the production of crops, livestock, livestock products, or in labor off the farm.

no definite indication as to the organization of the farm; thus does not measure the size or importance of the various enterprises that may be found on farms of similar acreages⁶

The 61 records for 1937 were arranged in four groups on basis of the productive man-work units (table 3). It will be noted that on the average, as the productive man-work units increased other measures of the size of business such as the acres operated, acres in tobacco, and productive animal units also increased but not in the same ratio. Of the first group of 15 farms, ranging up to 220.0 total productive man work units, the average labor income was \$177, and one-third of the farmers had negative labor incomes. In the second group of 16 farms, ranging from 220.1 to 300.0 total productive man-work units, the average labor income was \$348, and only two had negative labor incomes. In the third group, with total productive man work units ranging from 300.1 to 380.0, the average labor income was \$555 and only one farmer had negative labor income. There were 14 farms in the last group with total productive man-work units over 380.0, and the average labor income was \$744, a difference of \$567 more than the average for the first group. One farmer in this group also had a negative labor income. The data from 1935 showed similar tendencies when analyzed in the same way.

Table 3. Relations of productive man-work units to various factors—Robertson County, 1937.

Total productive man-work units Range	Average	Number of farms	Acres oper- ated	Acres in tobacco	Produc- tive animal units ¹	Labor in- come	Oper- ator's earnings
Up to 220.0	172	15	69	2.1	4.8	\$ 177	\$ 432
220.1-300.0	274	16	87	3.6	5.4	348	625
300.1-380.0	333	16	101	4.8	7.2	555	880
380.0 and over	469	14	141	7.1	9.6	744	1,143
Average all farms	309	61	99	4.3	6.7	\$ 451	\$ 764

1. A productive animal unit consists of one mature cow, or two heifers, or four calves or one bull or steer, or seven sheep, or fourteen lambs, or five hogs, or ten pigs, or one hundred chickens, or fifty turkeys.

2. Operator's earnings represents labor income plus the estimated value of the value of the farm dwelling and that part of the operator's family living furnished by the farm.

Other size factors—acres operated, capital invested, and gross receipts—showed a similar trend when sorted into similar groups. Thus, it is evident that, even on farms of family size, the tendency

6. A list of the average productive man-work units required for farm enterprises in this area is given in the Appendix, table 12.

for relatively larger farms to produce higher labor incomes. This is especially significant for the farms above 300 man-work units. The rough topography and the extra amount of labor associated with the farming systems on this kind of land, however, warrant special consideration of the advisability of expanding the farm unit much beyond that which can be operated with the farmer's own labor plus a limited amount of day labor or additional labor furnished by the farmer's family.

RELATION OF NUMBER OF LIVESTOCK AND NET LIVESTOCK RECEIPTS PER PRODUCTIVE ANIMAL UNIT TO LABOR INCOME

Number of Livestock. In 1937 there had been a slight decrease, since 1935, in the total number of livestock kept on the 61 farms. Horses and mules showed little change, but the number of cows, ewes, brood sows, and chickens declined (table 4). The decline in number of livestock was probably due, in part at least, to the drouth in this area during the summer of 1936. Lack of pasture, hay and other feed crops forced some of these farmers to adjust the number of livestock to the amount of farm-grown feeds available during the winter of 1936-1937.

Table 4. Average number of livestock per farm (March 1), Robertson County, 1937 and 1935.

Kind of livestock	1937 61 farms	1935 57 farms
Horses	2.1	2.1
Mules	0.1	0.2
Colts	0.1	0.1
Dairy cows	3.3	3.5
Heifers	0.5	0.5
Steers	0.1	0.3
Bulls	0.1	0.1
Ewes	11.8	13.7
Brood sows	0.2	0.3
Other hogs	0.6	0.4
Chickens	63	75
Turkeys	0.9	1.0

In 1937 all 61 farms kept workstock, sixty kept dairy cows, twenty-nine kept ewes, nine had brood sows, fifty-nine had chickens and twelve kept turkeys. Forty-six of the sixty farms which had cows kept four cows or less and only four farms had more than six. In 1935 the distribution of cows and heifers was similar.

In 1937, of the farms having ewes eleven had less than 20 head fourteen had 20 to 39 head and only three kept more than 40 ewes. In 1935, the flocks averaged larger, eighteen farms keeping over 20 and one farm over 50 ewes.

Livestock Products Sold Per Farm. Dairy products, eggs and wool were the major livestock products marketed by the 61 farmers. In 1937 the milk and cream sold amounted to an average of \$83 per farm or 53 percent of the total receipts from livestock products (table 5). Nine farmers sold whole milk and 43 of the remaining 52 sold cream. Most of the farms were not on a milk route and therefore were unable to sell whole milk. Eggs sold returned an average of \$47 per farm and wool averaged \$20 per farm in 1937. The total livestock receipts averaged \$2.65 more in 1935 than in 1937.

Table 5. Livestock products sold in 1937 and 1935, average per farm Robertson County.

Livestock Products	1937 61 farms	1935 57 farms
	dollars	dollars
Butterfat (cream)	47.00	47.00
Market milk	36.00	41.00
Eggs	47.00	52.00
Meat (pork)	1.00	0.21
Wool	20.00	16.00
Breeding fees	3.00	0.44
Total livestock products sold	154.00	156.65

The receipts from livestock products sold amounted to about \$3.00 per week on these farms, for both years. This type of income is fairly stable regardless of weather conditions and comes in continuously throughout the year, providing farmers with considerable cash to meet current expenses. Farms of this type generally have relatively low cash expenses, but few farmers are able to save enough cash from their tobacco crops to provide for this continuous outlay from one season to another.

Efficiency in handling livestock has considerable influence upon farm income. To study this relationship the 61 records for 1937 were divided into two groups on the basis of the productive animal units per farm, in order to partially eliminate the influence of the number of productive livestock upon the labor income. Each of these groups was then subdivided into two, on the basis of net livestock receipts per productive animal unit (table 6)⁷

7. Net livestock receipts also include inventory changes.

There were 29 farms with less than 6.1 productive animal units, and in the first subgroup there were 18 farms with less than \$46 net livestock receipts per productive animal unit and these farms averaged \$24 per farm for this factor. The average labor income for this group of 18 was \$255; one-third of these farms had negative labor incomes. The 11 farms in the second subgroup with net livestock receipts per productive animal unit above \$46 averaged \$70 for this factor and had labor incomes averaging \$420. In this subgroup only one farm had a negative labor income.

Table 6. Relation of number of livestock and net livestock receipts¹ per productive animal unit to labor income, 61 farms, Robertson County, 1937.

Items	Net livestock receipts per productive animal unit			
	Less than \$46		\$46 or more	
	6 P.A.U. ² or less per farm	More than 6 P.A.U. per farm	6 P.A.U. or less per farm	More than 6 P.A.U. per farm
Number of farms	18	11	16	16
Acres operated	67	69	133	122
Average net livestock receipts per productive animal unit, dollars	24	70	33	63
Productive animal units	3.6	3.6	9.8	9.2
Spent for feed, dollars	32	29	51	90
Labor income, dollars	255	420	401	744
Operator's earnings, dollars	550	685	737	1,084

¹ Includes inventory increases

² P. A. U. Stands for productive animal units.

Of the 32 farms having over six productive animal units, 16 had net livestock receipts per productive animal unit of less than \$46 and average \$33 per farm for this factor. Within this subgroup the labor incomes averaged \$401, and two farmers had negative labor incomes. In the other subgroup the 16 farms with over \$46 net livestock receipts per productive animal unit averaged \$63 for this factor and had average labor incomes of \$744. All the farmers in this group had positive labor incomes.

It will be noted (table 6) that the farmers with an average of only 3.6 productive animal units with good livestock efficiency had higher labor incomes, on the average, than the farmers with an average of 9.8 productive animal units who were less efficient in handling their livestock. Altho not all of this increase in average labor income can be credited to livestock production, the figures in-

dicating the relative profitableness of taking good care of livestock and following good practices of feeding, breeding and marketing.

In preparing table 6, the proportion of the net livestock receipts from each kind of livestock was also computed. It was found that on the farms with less than 6.1 productive animal units about one-half of the receipts were from dairy cattle, about three-eighths from poultry and about one-eighth from sheep. On the farms with over six productive animal units the livestock receipts from dairy cattle made up slightly less than one-half, receipts from sheep about one-third and receipts from poultry slightly more than one-sixth of the total net livestock receipts. An analysis of the relationship of livestock receipts per productive animal unit for the year 1935 showed that the farms with the largest number of animal units also earned higher than average incomes for that year.

RELATION OF CROP ACREAGE AND YIELD TO LABOR INCOME

Crops Grown. The crops grown on the 61 farms in 1937 consisted of an average per farm of 6.5 acres of corn, 4.3 acres of white burley tobacco, 2.8 acres of wheat harvested, 3.3 acres of alfalfa, 4.1 acres of timothy and other hay, and 0.9 acre in other crops, garden and truck, making a total of 22.7 acres in harvested crops. These farms had slightly more corn, wheat and alfalfa in 1935, but they had 1.4 acres less tobacco per farm than in 1937. It is probable that the very unfavorable weather in the spring and summer of 1935 accounted for the small acreage of tobacco. Table 7 shows a comparison of crops grown on these farms in 1935 and 1937.

In 1937 all the farmers grew white burley tobacco and the acreage per farm ranged from one-half acre to 12.9 acres. About one-third of them grew less than three acres, and about one-sixth grew over six acres per farm. Fifty-seven of the 61 farmers grew corn. The acreage per farm ranged from one to 22 acres. About half of them grew less than six acres of corn and only three grew more than 12 acres. Wheat was harvested by 30 of the 61 farmers and the range was 1.8 to 2.2 acres per farm. Forty-two of them grew alfalfa with a range per farm from one to 15 acres. Eight of the farmers who grew alfalfa had less than three acres, twenty-three grew 3 to 5 acres, six grew 6 to 8.9 acres and five grew 10 acres or more.

The acres of wheat or other small grain sown in the fall give an indication of the proportion of the land which was protected from leaching and erosion over the winter by a cover crop. In order to

keep all the cultivated land covered it is necessary to sow as many acres of some cover crop (wheat, rye, oats or barley) as there were acres in corn and tobacco or other intertilled crop. Only 30 of the farmers reported harvesting wheat or other small grain in 1937. Although some of the other 31 farmers sowed wheat on part of their tobacco and corn land, a considerable part of their cultivated land was left bare over the winter. Since the average slope of the farms is over 23 percent, leaving the cultivated fields unprotected is a serious matter, for it is practically impossible to conserve the soil without the use of cover crops.

Table 7. Average crop acreages and size of farms, Robertson County, 1937 and 1935.

Crop	1937 61 farms	1935 57 farms
	acres	acres
Corn	6.5	7.1
Tobacco	4.3	2.9
Wheat	2.8	3.5
Alfalfa	3.3	5.2
Timothy	2.7	2.2
Clover and timothy	1.2	2.3
Other hay	1.0	0.5
Other crops ¹	0.3	0.1
Garden and truck	0.6	0.9
Total (all harvested crops)	22.7	24.7
Open pasture	46.4	43.2
Other land ²	28.7	30.5
Whole farm	98.8	98.4

¹ 1 Oats, sorghum and seed crops.

² Includes, in 1937, 22.4 acres of brush pasture, 1.4 acres of woods pastured, 3.1 acres of woods not pastured and 2.8 acres in waste, roads, etc. Includes, in 1935, 23.1 acres of brush pasture, 1.6 acres of woods pasture, 2.9 acres of woods not pastured and 0.8 acres in waste, roads, etc.

If these farmers continue to grow the same proportion of corn and tobacco as in 1937, they will have to plow all their land, on an average, every 6.4 years. Since they have an average of 69 acres of tillable land with 10.8 acres of corn and tobacco each year, the rotation could not exceed six years in length. The opinion of the better farmers in this area is that longer rotations and an ample vegetative growth are needed to protect the soil from serious erosion on most of the fields now used for cultivated crops.

Crop Yields. Crop yields, on the farms studied, averaged considerably higher in 1937 than in 1935 (table 8). The average yield of corn on the 61 farms in 1937 was 29.1 bushels per acre as compared with 21.8 bushels per acre on 57 of the same farms in 1935. Wheat

yields averaged 5.9 bushels per acre more on these farms in 1937. The most striking difference in yields for the two years is shown in the average increase of 201 pounds per acre for tobacco in 1937. The average yield per acre was 789 pounds in 1937 as compared to 588 pounds in 1935.

Table 8. Average crop yield, Robertson County, 1937 and 1935.

Crop	1937 61 farms	1935 57 farms
Corn, bushels	29.1	21.8
Wheat, bushels	16.4	10.5
Tobacco, pounds	789.0	588.0
Alfalfa hay, tons	1.0	1.7
Small-grain hay, tons	0.9	1.0
Other hay, tons	0.9	0.8

In 1937, the range in the yield per acre of tobacco on the 61 farms was from 295 to 1200 pounds. Eighteen percent of the farms had yields below 500 pounds; 25 percent, 500 to 800 pounds; 36 percent, 801 to 1000 pounds, and 21 percent, above 1000 pounds. The range in tobacco yield was even wider on the same farms in 1935. Yield on the 57 farms in 1935 ranged from 150 to 1212 pounds per acre. Thirty-seven percent had yields below 500 pounds; 49 percent, 500 to 800 pounds, and only 14 percent had yields above 800 pounds. Such wide year-to-year fluctuations in the yield of tobacco, the principal cash crop, exert a considerable influence on farmers' income in this area.

The state average yield of burley tobacco, in 1935, was 766 pounds per acre, and in 1937, 905 pounds.⁸ These Robertson County farms had tobacco yields averaging 23 percent lower than the state average in 1935 and 13 percent lower in 1937.

Relation of Tobacco Yield to Labor Income. To determine the relationship of yield of tobacco to labor income, the 61 farm records were first sorted into two groups according to whether they had less or more than four acres of tobacco. Then, within each of these groups, the records were subsorted on yield of tobacco per acre. On farms that grew less than four acres of tobacco an increase in the average yield from 574 to 994 pounds was associated with an average increase of \$327 in labor income (table 9).

8. United States Department of Agriculture, Crops and Markets, Volume 13, number 4, April, 1936; volume 14, number 12, December, 1937; and volume 15, number 5, May, 1938.

Table 9. Relation of acreage, yield and price of tobacco to labor income, Robertson County, 1937.

Item	Farms with less than 4 acres of tobacco		Farms with 4 acres or more of tobacco	
	Yield under 800 lbs. per acre.	Yield 800 lbs. or more per acre.	Yield under 800 lbs. per acre.	Yield 800 lbs. or more per acre.
Number of farms	11	19	14	17
Acres operated	75	94	109	111
Lbs. tobacco per acre	574	994	532	965
Percent tillage land				
in tobacco	5.7	3.4	9.1	7.6
Acres in tobacco	2.5	2.5	6.1	6.1
Price per lb. of tobacco, dollars	.18	.24	.20	.22
Fertilizer expense per farm, dollars	4	14	16	22
Labor income, dollars	114	441	376	742
Operator's earnings, dollars	357	764	695	1,083

In the third and fourth subgroups, with identical average acres of tobacco, an increase in the average yield from 532 pounds to 965 pounds per acre was associated with an increase of the average labor income from \$376 to \$742. It is significant that the farms with an average of 2.5 acres of tobacco and yield above 800 pounds, made higher labor incomes than those with an average of 6.1 acres, with yields below 800 pounds. This indicates that one way to increase profits on these farms, from tobacco production, is to reduce the acreage per farm and increase the yields by better land management and more efficient handling of the crop. On the average, the farmers producing the higher tobacco yields spent more money for fertilizer and had a smaller percentage of their tillable land in tobacco than the farmers with yields below 800 pounds per acre.

There was a definite tendency for the farmers with the higher tobacco yields to receive the higher prices for their crops (table 9). The farmers in the group with less than four acres of tobacco but with yields of 800 pounds per acre, or more, averaged six dollars per hundred more than those whose yields were below 800 pounds. This same relationship also existed, but to a lesser degree, on the farms growing four acres or more of tobacco. In this group the farmers with yields of 800 pounds or more per acre, averaged two dollars per hundred more for their tobacco than those whose yields were below 800 pounds. This relationship between tobacco yield and price further emphasizes the importance of following farming practices which produce higher yields of tobacco per acre.

RELATION OF WEATHER CONDITIONS TO LABOR INCOME

The very low yields of all harvested crops except hay, in 1935 (table 8), were due largely to the excessive rainfall in Robertson County in that year. The rainfall thruout the growing season was much above normal. (See Appendix, table 14.)⁹ The average precipitation is reported by five-day intervals because, in this area, usually requires about five days for the soil to dry sufficiently to permit farming operations after a heavy rain, particularly in the spring. In figure 2 the average precipitation is shown by five-day interval from March thru September, for 1935 and 1937. During these seven months of the growing season in 1935 the rainfall averaged one inch or more for eighteen of the forty-three five-day periods. In contrast during this same period of 1937, the rainfall, by five-day periods, averaged one inch or more only five times. The normal rainfall for the same seven months is 26.28 inches. In 1935 the rainfall was 41.1 inches, or 15 inches above the normal for this period, and in 1937 it was 20.64 inches, or 5.64 inches below normal.

The monthly temperature and the departures from normal, as reported in Appendix, table 11, for the years 1935 and 1937. For each year as a whole the average departures from normal were very small; however, for April, May and June, the temperature was below normal in both years. Lower than normal temperature in the spring retards the rate at which the soil dries after a rain and prevents farming operations for a longer time than when the temperature is normal or above. The subnormal temperature coupled with the excessive rainfall in the spring of 1935 made this year very unfavorable for the production of intertilled and small-grain crops.

Besides reducing crop yields by producing unfavorable growing conditions the large amount of rainfall also probably reduced the acreage of crops planted, especially tobacco, and affected adversely the quality of tobacco produced; the high rainfall and humid conditions in August and early September caused damage to the tobacco in the field prior to and during harvesting, and houseburning of the curing barns. The high rainfall also reduced the acreage planted to tobacco by causing unfavorable conditions for breaking and preparing the land. The Eden Clay Loam and to some extent the other soils in this area have qualities which cause them quickly become too wet for cultivation and also excessively hard, following

9. Since there was no weather station in Robertson County, the average rainfall at Cynthiana and Maysville was used as an indication for the county.

rain in the spring, thus limiting the number of days which the land may be worked in rainy seasons.

The experience of many successful farmers shows that the land management program followed on farms in the Eden Shale area affects directly the crop yields obtained in both good and bad seasons. Low yields usually are associated with short rotations, lack of cover crops on the land in winter, and removal of all crops with-

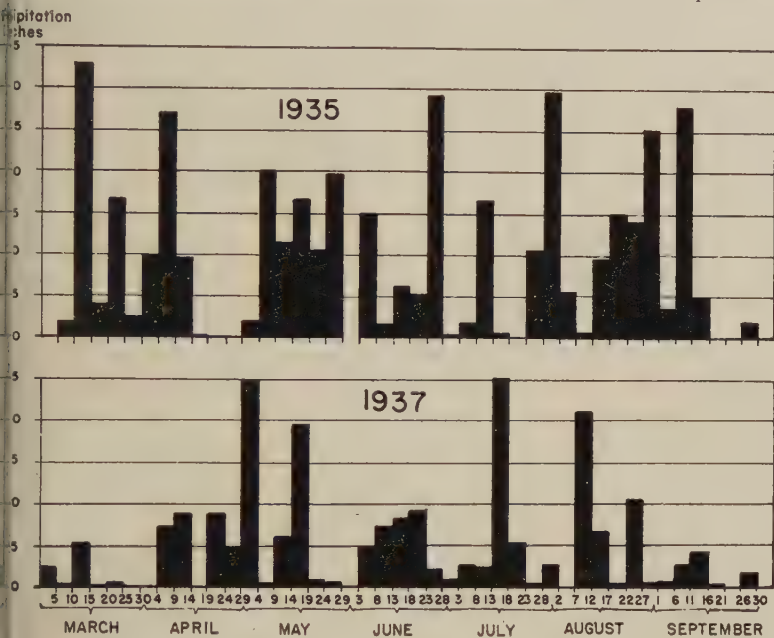


FIGURE 2. Distribution of precipitation by five-day intervals, March 1 to September 30, 1935 and 1937.

not returning sufficient soil-building materials such as manure, crop residues, commercial fertilizers and ground limestone.¹⁰ Pasturing too closely also has an influence toward lower yields. Pasturing all grain instead of harvesting it favors increased yields, and the establishment of a good sod aids greatly in controlling erosion during the period from one cultivated crop to another. The sod, by adding organic matter to the soil, aids it in absorbing and retaining sufficient moisture for the crops. The low yields caused largely by short rotations, lack of cover crops and sod were in evidence on

10. Bondurant, John H., Factors for Profitable Farming on Limestone Hill Land of Eden Formation in Kentucky. Kentucky Agricultural Experiment Station Bulletin 384, August, 1938.

many farms in 1937 when a relatively normal rainfall prevailed during the growing season.

On the other hand, many farmers had relatively good yields both in 1935 and 1937. An examination of these cases revealed that the farmers were following a better-balanced system of farming than others. A common cropping program was tobacco or corn followed by a small-grain cover crop (usually wheat) and then seeded to a mixture of alfalfa and timothy or lespedeza and timothy; these crops were cut for hay for two to six years and then pastured two to three years or more before plowing for an intertilled crop.

A typical farm with a long rotation and considerable pasture and hay crops usually consists of about 80 to 120 acres of tillable land. About 10 to 15 acres of corn and tobacco are raised and the same acreage of small grain, pastured or harvested for grain, 20 to 30 acres of hay and 40 to 60 acres of pasture. The livestock kept consists of two or three work animals, 20 to 40 sheep, five to seven dairy cows, 60 hens and one brood sow. The hay and pasture produced are usually sufficient to meet the requirements of the livestock and enough corn and concentrated feed is purchased to supplement the corn produced on the farm. Altho the production of corn is questionable, considering the usual return from the crop and the expense involved, it is often necessary to plow certain fields in order to renew the sod and pasture. For this reason corn is produced as a part of the program of restoring hay and pasture crops, particularly on thin land not suited to tobacco production.

Many farms in the area are in a low state of productivity and would require considerable time and care to restore their fertility. The usual procedure is to start one field a year with a plan for fertilizing and liming, when necessary, sow a mixture of grasses and legumes following a cultivated crop and protect the land from erosion and leaching during this period by a small-grain cover and nurse crop. This program extended from field to field, may require 10 to 15 or more years for its completion, especially if the farmer must make a living on the farm at the same time that he is increasing its productivity. During this period careful planning of expenditures for the farm and family is of prime importance. An unforeseen expenditure such as a large hospital bill, or bad weather conditions resulting in poor production may interfere seriously with the program.

According to data obtained by the Soil Conservation Service t

majority of farms in the central and northern part of Robertson County consist of rolling and steep land locally known as ridge and hill land respectively. There is usually a much larger acreage of hill land than of ridge land of most farms in the area. Ridge land of the same state of productivity as the hill land normally produces more tobacco, all seasons considered, than the hill land. In many instances, however, the ridge land, because of the tendency to overwork it, is depleted to such an extent that it is not as good for tobacco as the hill land. Some of the ridge land requires limestone in order to produce legumes successfully. By the application of limestone, growing legumes and protecting the land from erosion, it is practical to build it up until it becomes very good tobacco land. A favorable factor in the production of tobacco on this land is that it can ordinarily be produced with much less labor than on hill land. Successful rotation to keep ridge land in a good state of productivity for tobacco is to follow the crop with wheat, pastured or harvested, lespedeza or red clover for hay for two years and two or three years of pasture. Rotations often followed on the hill land are tobacco or corn, wheat pastured, alfalfa and timothy hay for three or four years and pasture for four or more years before being plowed again. This land grows alfalfa without the use of limestone, but application of phosphate may improve the hay yields.

SUMMARY

Information for this study was secured from farmers in the central and northern part of Robertson County, for the years, 1935 and 1937. More than three-fourth of the soil on the farms was classified as Eden Clay Loam by the Soil Conservation Service. This soil is found mainly on the steep slopes, and much of it is badly eroded. The other soils on the ridge tops are known locally as "ashy land". Most of this "ashy land" caps the ridges or occurs on the gentle slopes. Practically all the farms have considerable steep or stony land.

Chiefly because of more favorable weather, yields of tobacco, wheat and wheat averaged considerably higher in 1937 than in 1935. The cash farm income from tobacco and total farm receipts fluctuated widely on the same farms in the two years. A greater yield, higher price and larger acreage of tobacco were responsible for the fact that tobacco receipts for 1937 exceeded those of 1935 by \$515 per acre. Altho crop receipts fluctuated widely the receipts from live-

stock were practically the same for the two years. The relative stability of receipts from livestock emphasizes the importance of diversity and balance for the farm enterprises on farms in this area.

Tobacco and corn were the principal intertilled crops, and alfalfa, timothy and clover were the chief hay crops grown on the farms. Wheat was the principal small grain. On the same farms the acreage of corn, wheat and alfalfa decreased in 1937 as compared with 1935, while the acreage of tobacco increased. Dairy cattle, sheep and poultry were the principal kinds of livestock. The number of livestock changed very little from 1935 to 1937.

Total farm receipts averaged \$735 per farm in 1935 and \$1,200 in 1937. Labor incomes varied widely in both years, averaging \$1,000 in 1935 and \$451 in 1937. In addition to labor income these farmers also had the use of farm dwelling, fuel, and farm-produced food products valued at \$347 in 1935 and \$313 in 1937. The size of the business, tobacco yields, and net livestock receipts per production animal unit were the principal factors affecting the variations in labor income for the same year.

Two of the most important ways in which incomes were increased or stabilized were maintaining the proper balance between livestock and crop enterprises and following land-management practices that increased yields and produced burley tobacco of a high quality.

The application of phosphate fertilizer and limestone on the ridge land makes possible the production of legumes and grasses and results in increased yields of higher quality tobacco as well as in increasing the capacity of the farm for carrying livestock.

Farms of sufficient acreage to develop a system of farming requiring from 300 to 500 productive man-work units produced the most satisfactory incomes. Farms of this size producing above average tobacco yields and above average receipts per animal unit made higher than average labor incomes. Expansion of the farm operation much beyond that which can be operated with the farm family labor, however, warrants special consideration.

The value of the food furnished the family by the farm, at farm prices, averaged \$190 per farm in 1935 and \$166 in 1937, being equivalent to 59 percent of the net farm income in 1935 and 22 percent in 1937. Thus it is evident that the well-being of farm families in this area is dependent in a high degree upon the production of an ample supply of food for home use.

APPENDIX

The following tabulations of data are inserted here for reference.

Table 10. Total farm expenses, averages, Robertson County, 1937 and 1935.

Item	1937 61 farms	1935 57 farms
	dollars	dollars
Cropper labor ¹	147	31
Hired labor and board	31	19
Repairs to buildings	13	18
Repairs to fences	3	10
Repairs to machinery	7	7
Feed-grain purchased	39	28
Hay and roughage purchased	13	8
Seeds and plants	29	19
Fertilizer and limestone	22	1
Tobacco cotton, threshing and other crop expenses	13	13
Veterinary and other livestock expenses	7	7
Taxes	47	50
Insurance	8	10
Trucking	8	6
Auto for farm use	13	20
Miscellaneous expense	3	13
Total current farm expense	403	260
Depreciation	75	84
Unpaid family labor	53	68
Net decrease in inventories	—	6
Total farm expenses	531	418

¹The value of the cropper's share of crops is charged as cropper labor expense.

Table 11. Normal, monthly and annual mean temperature with departure from the normal, Maysville, 1935 — 1937.¹

Month	Normal mean temperature	Mean Temperature		Departure from the Normal	
		1935	1937	1935	1937
	degrees F.	degrees F.	degrees F.	degrees F.	degrees F.
January	33.7	35.1	42.6	1.4	8.9
February	35.1	38.7	35.5	3.6	0.4
March	44.3	52.6	39.6	8.3	-4.7
April	54.3	53.3	53.5	-1.0	-0.8
May	64.5	62.8	62.2	-1.7	-2.3
June	72.9	71.4	72.2	-1.5	-0.7
July	76.8	80.0	75.0	3.2	-1.8
August	75.2	77.0	77.4	1.8	2.2
September	69.7	68.2	67.8	-1.5	-1.9
October	57.4	57.8	55.4	0.4	-2.0
November	45.2	46.6	42.5	1.4	-2.7
December	35.3	28.3	34.0	-7.0	-1.3
Annual	55.4	56.0	54.8	0.6	-0.6

¹Climatological Data, Annual Reports, Weather Bureau, Kentucky Section, Louisville.

Table 12. Average productive man-work units required for farm enterprises in the Bluegrass hill region.

Enterprises	Man-work units
Burley tobacco, per acre	32.5
Corn, per acre	
Shocked and cribbed	4.5
Husked from stalks	3.0
Silage	4.3
Wheat, rye or barley, per acre (including threshing)	1.4
Oats (threshed)	1.6
Hay, per acre	
Clover, timothy or mixed	1.1
Redtop	0.7
Alfalfa (3 cuttings)	2.0
Japan clover	1.0
Cowpeas or soybeans	2.0
General truck (garden) per acre	30.0
Dairy cattle, per cow (including calves)	
Milk cow, selling cream or wholesale milk	12.5
Milk cow, milk retailed	18.3
Dairy heifer	1.0
Bull (on pasture)	4.0
Beef cattle, per head (feeders)	1.0
Beef cows (including calves)	1.5
Horses and mules, per head	
Workstock	4.0
Colt	1.0
Hogs	
Brood sow and fattening pigs to market weight	8.0
Brood sow and pigs to weaning (two litters)	3.0
Fattening hogs, per 100 lbs. gain	0.6
Sheep, per head	0.6
Poultry, per 100 hens	6.0
Raising 100 chicks	7.5
Turkeys	1.2

Table 13. Farm business summary, averages, Robertson County, 1937 and 1935.

Item	1937 61 farms	1935 57 farms
Number of farms	61	57
Size of farm (acres)	99	98
Total capital invested	\$6043	\$6129
Total receipts	1284	741
Total expenses	531	418
Net farm income	753	323
Interest on investment at 5 percent	302	306
Labor income	451	17
Value of family living from the farm	313	347
Operator's earnings	\$ 764	\$ 364

Table 14. Precipitation. Monthly normal and by five-day intervals in March thru September. Averages of the U. S. Weather Bureau records at Cynthiana and Maysville, 1935 and 1937.¹

Intervals	Acreage precipitation		Monthly precipitation		Monthly normal pre- cipitation
	1935	1937	1935	1937	
	inches		inches		inches
March 1—March 5	0.00	0.27			
March 6—March 10	0.23	0.07			
March 11—March 15	3.34	0.56	6.85	1.02	4.19
March 16—March 20	0.45	0.01			
March 21—March 25	1.69	0.09			
March 26—March 30	0.28	0.00			
March 31—April 4	1.02	0.00			
April 5—April 9	2.74	0.75			
April 10—April 14	0.98	0.00			
April 15—April 19	0.02	0.90	4.35	4.61	4.01
April 20—April 24	0.00	0.48			
April 25—April 29	0.22	2.47			
April 30—May 4	2.02	0.07			
May 5—May 9	1.17	0.61			
May 10—May 14	1.69	1.96			
May 15—May 19	1.06	0.10	7.83	2.84	3.46
May 20—May 24	1.97	0.08			
May 25—May 29	0.00	0.00			
May 30—June 3	1.50	0.49			
June 4—June 8	0.18	0.73			
June 9—June 13	0.64	0.84			
June 14—June 18	0.54	0.94	5.70	3.35	3.68
June 19—June 23	2.95	0.22			
June 24—June 28	0.02	0.11			
June 29—July 3	0.18	0.29			
July 4—July 8	1.66	0.27			
July 9—July 13	0.21	2.54			
July 14—July 18	0.00	0.54	6.68	3.99	3.86
July 19—July 23	1.07	0.05			
July 24—July 28	2.99	0.28			
July 29—Aug. 2	0.56	0.00			
Aug. 3—Aug. 7	0.02	2.11			
Aug. 8—Aug. 12	0.97	0.66			
Aug. 13—Aug. 17	1.50	0.03	6.77	3.90	3.87
Aug. 18—Aug. 22	1.40	1.05			
Aug. 23—Aug. 27	2.51	0.03			
Aug. 28—Sept. 1	0.36	0.05			
Sept. 2—Sept. 6	2.78	0.28			
Sept. 7—Sept. 11	0.48	0.42			
Sept. 12—Sept. 16	0.00	0.02	3.50	0.94	3.21
Sept. 17—Sept. 21	0.00	0.00			
Sept. 22—Sept. 26	0.17	0.17			
Sept. 27—Sept. 30	0.05	0.00			
Total Mar. 1—Sept. 30	41.70	20.64	41.70	20.64	26.28

¹ Climatological Data, Annual Reports, U.S.D.A., Weather Bureau, Kentucky, Section Maysville.

Kentucky Agricultural Experiment Station

University of Kentucky

COST OF CURING WHITE BURLEY TOBACCO WITH ARTIFICIAL HEAT

BULLETIN NO. 406



Lexington, Kentucky

July, 1940

(333)

CONTENTS

	Pa
Fuel requirements and costs	3
Labor requirements	3
Stove requirements and costs	3
Barn requirements and costs	3
Curing and drying costs	3
Fire-curing practices	3
Summary	3

COST OF CURING WHITE BURLEY TOBACCO WITH ARTIFICIAL HEAT

By GEO. B. BYERS¹

White Burley tobacco has furnished to Kentucky farmers a larger share of cash income than any other crop, for the past 25 years or more. During the last ten years the lighter-weight and brighter-colored white Burley tobacco has commanded the highest prices. In producing the lighter-weight tobacco, farmers have set the plants closer in the rows and the rows closer together, topped the tobacco earlier and suckered it less often. As a result, more stalks per acre and thinner leaves had to be housed, thereby bringing about a pressure to crowd the larger volume of tobacco into the available curing space. As a means of taking care of this crowding and as an additional means of producing the lighter-colored tobacco more profitably, more Burley growers each year have cured their tobacco with artificial heat.

This study presents the fuel, labor, equipment and housing requirements as shown by survey records obtained on 63 farms for 1938 and 32 farms for 1939 where Burley tobacco was cured with artificial heat, and on 22 farms for 1938 where the tobacco was air cured. These farms were in Bourbon, Clark, Fayette, Harrison, Jessamine, Mason and Woodford Counties.

The practice of using artificial heat in curing Burley tobacco has been followed by several farmers of the Bluegrass Area for 25 to 60 years. In recent years this practice has spread so that over one-half of the farmers included in this study, who used heat in curing their Burley tobacco in 1938, had followed the practice 10 years or more, previously, while an additional one-fourth of them had followed it 6 to 10 years.

Most of the farmers interviewed in 1939 considered the use of artificial heat in curing Burley a practice to be followed year after year. Most of them also used heat as a supplement to air curing when they did not need to keep the fire going continuously during the curing period. However, an increasing number considered it desirable to fire continuously from housing or a few days after,

¹The author wishes to acknowledge the assistance of County Agents in Bourbon, Clark, Fayette, Harrison, Jessamine, Mason and Woodford Counties, and farmers who generously gave their time and data which make this publication possible.

until the tobacco was completely cured, even in weather favorable for air curing.

The use of artificial heat in curing tobacco required expenditures for fuel, labor and stoves. Labor was used in preparing the barn for firing, starting fires, replenishing fuel, removing ashes and sometimes, watching the fires, as a precaution to keep the tobacco from catching on fire. Where coke was used as fuel, firing was done in stoves. Firing costs were offset to some extent since the use of artificial heat made it possible to house more tobacco in a given space. Higher price paid for tobacco with lighter color and higher quality which was obtained in proper curing with artificial heat was a further incentive for firing even though it increased the cost of producing Burley tobacco.

Fuel Requirements and Costs. Fuel was the largest item of cost in firing Burley tobacco. Coke, charcoal briquets and petroleum coke were used as fuels. Coke was used most commonly while petroleum coke was used the least. Many farmers mentioned difficulty in getting petroleum coke and dissatisfaction with results obtained from its use. Charcoal briquets, a relatively new kind of fuel, were used by five farmers in 1938 and thirteen farmers in 1939. Some of these farmers mentioned the high cost of charcoal briquets and the belief that insufficient heat was produced by them.

The heat from the coke fires was more noticeable because of the amount of fuel used and the arrangement of the fires. The amount of heat produced by equal weights of the two fuels is very slightly greater for the charcoal briquets. Since the charcoal briquet fires, however, were smaller, more numerous and more advantageous when placed over the floor of the barn, the heat from them was more uniform over the entire barn than from coke fires. In this connection it should be recognized that the use of heat in curing tobacco is primarily a matter of providing the best humidity and creating a circulation of air to carry away moisture given off by the tobacco. For example, experiments have shown that variation in temperature causes little or no difference in the quality of the tobacco when the temperature remains between 65 to 85 degrees Fahrenheit.

Approximately three and one-half times as much coke as charcoal briquets was used per acre per day by the farmers included in this study. (Table 1.) The larger amount of coke was used because of the necessity of having a considerable body of coals to keep

the coke burning and because many farmers tried to make one stove or bent furnish heat enough to control humidity of the entire tent. As a result, a large amount of the heated air, undoubtedly, was carried up directly thru the tobacco without becoming fully saturated with moisture from the tobacco before it passed out of the barn. If it were possible to distribute a large number of small coke fires over the entire floor of the barn as was the case with charcoal briquets, it would seem that there should be little difference in amounts of fuel required. The fact, however, that it is necessary to have the large body of coals when using coke apparently kept these farmers from curing their tobacco with as small amount of coke as with charcoal briquets.

The amounts of fuel used in 1938 and 1939 differed greatly because the weather of the two curing seasons differed. The rainy period during the latter part of September, 1938, caused farmers to continue firing longer than usual. Some farmers thought of this additional firing as an unusually long curing period while others passed it as an additional drying period. For the drying period many farmers allowed the fires to go out and only rekindled them when they thought the tobacco was in too high "case". In the section of the state where the records were obtained the curing season of 1939 was usually dry except a "wet" week in the latter part of August which affected the early housed tobacco. Since the length of firing periods for the two years varied, the amount of fuel used per day for an acre of tobacco cured with artificial heat furnished the most satisfactory measure for comparison.

Fifty-four farmers used an average of 86 pounds of coke per day for each acre of tobacco cured with artificial heat, during a 12.2 day period, in 1938. (Table 1.) An additional 42 pounds of coke per day for each acre of tobacco was used in drying the tobacco, for an average of 4.1 days, by 24 of these farmers. In general, the farmers did not fire as intensively during the drying period as during the curing period, as is evidenced by the smaller amount of fuel used. The firing practices varied from farm to farm. However, a general practice was to keep the temperature lower during the first few days than for the period immediately following. Generally the temperature was allowed to taper off toward the end of the curing period. Because of this method of firing, the longer secondary firing period used less fuel, on the average, per day of firing than the shorter

initial firing period. In an 8-day curing period, 19 farmers in 1938 used an average of 90 pounds of coke per day for each acre of tobacco.

Table 1. Amount and cost of fuel per acre and per acre per day curing and drying Burley tobacco with artificial heat.

	Kind of fuel					
	Coke		Charcoal briquets		Coke and charcoal briquets	
	1938	1939	1938	1939	1938	1939
CURING						
Number of farms	54	19	5	13	5	9
Number of barns	138	32	9	15	6	13
Average number of days	12.2	8	8.6	7.2	18.1	11
Pounds of fuel						
Per acre	1043	719	206	176	398	559
Per acre per day	86	90	24	24	22 ¹	51
Cost of fuel, dollars						
Per acre	4.19	2.90	3.64	3.27	3.84	3.8
Per acre per day	0.34	0.36	0.42	0.45	0.21	0.3
DRYING						
Number of farms	24	2	5	2	1	2
Number of barns	50		9		1	
Average number of days	4.1		4.4		7	
Pounds of fuel						
Per acre	172		106		154	
Per acre per day	42		24		22	
Cost of fuel, dollars						
Per acre	0.69		1.86		1.48	
Per acre per day	0.12		0.42		0.21	

¹ This wide variation was apparently caused by different proportions of coke and charcoal for the two years.

² In 1939 only one man did any firing to dry the tobacco after it was cured.

Five farmers used an average of 24 pounds of charcoal briquets per day for each acre of tobacco cured with artificial heat during an 8.6 day period, in 1938. (Table 1.) These farmers used a similar amount of charcoal briquets per day during a period of 4 days while drying the tobacco. Thirteen farmers used 24 pounds of charcoal briquets per day for each acre of tobacco cured with artificial heat in 1939.

Another group of farmers included in the study used both coke and charcoal briquets in the same barn. The amount of fuel used per day varied greatly because of the varying proportions of coke and charcoal briquets and the varying length of firing period. Some of the farmers used the charcoal briquets only as a means of kindling the fires because this method made it possible to sta

the fires in the barn. Others used coke in stoves in the center of the bents and charcoal briquets in small holes dug in the ground in the sheds of each bent.

The cost of fuel per day of firing was slightly higher for charcoal briquets than for coke. While less fuel was used per day for each acre in firing with charcoal briquets than with coke, the difference in purchase price of the two fuels more than offset the difference in amounts used. Charcoal briquets cost these farmers \$35.25 per ton, in 1938, and \$37.19 per ton, in 1939. The coke cost \$8.04 per ton in 1938 and \$8.06 per ton in 1939.

The fuel was usually purchased by the landlord on 49 of the farms on which the tobacco was raised by tenants. Over three-fifths of the landlords purchased all the fuel for curing the tobacco. On all but one of the remaining farms the tenants purchased half of the fuel. One tenant purchased all the fuel.

The total cost of coke used in curing tobacco during a period of 12.2 days averaged \$4.19 per acre for 54 farmers while additional fuel used in drying the tobacco for 4.1 days cost 24 of these farmers 69 cents per acre of tobacco dried. In 1939, when no firing was done to dry the tobacco, the total cost of coke in curing the tobacco was \$2.90 per acre for 8 days of firing. The coke cost 34 cents per day for each acre of tobacco cured by these farmers in 1938 and 36 cents per day for each acre in 1939. (Table 1.)

Charcoal briquets used by 5 farmers in 1938 cost \$3.64 per acre for 8.6 days of curing with an additional \$1.86 per acre for 4.4 days of drying. In 1939, drying was not done and 13 farmers had an average cost of \$3.27 per acre for 7.2 days curing with charcoal briquets. The charcoal briquets cost 42 cents per day in 1938 and 45 cents per day for each acre of tobacco cured with artificial heat, in 1939.

A combination of coke and charcoal briquets showed a low cost per day because of a long curing and drying period in 1938 but the cost per day was very similar to that of coke or briquets. In 1938 the cost was about the same as coke but lower than charcoal briquets.

Labor Requirements. Labor was the second important item of cost of curing Burley tobacco with artificial heat. Curing with artificial heat increased the labor requirements in the production of tobacco because the barn had to be prepared for firing, the fires started, the fuel replenished and, in some cases, the fires watched

day and night. Kind of fuel, length of firing period and frequency of tending fires influenced the amount of labor required. Since the fires were frequently started before housing the tobacco was completed, the additional labor represented a cash expense for extra hired help on many farms.

Raking up and removing the loose leaves and stalks from the floor and other work in preparing the barn for firing required about one-half hour for each acre of tobacco fired with coke, one hour per acre for the tobacco fired with charcoal briquets and about two-thirds of an hour for the tobacco fired with both coke and charcoal briquets. (Table 2.) About half the farmers cleaned the bents when they were filled and did not show any time required to prepare the barn for firing. Farmers who used charcoal briquets did additional work in preparing the barn for firing in that they dug a hole 8 or 10 inches in diameter and 8 or 10 inches deep in the dirt floor for every 60 to 75 square feet of floor space. Once the holes had been dug, the time required to prepare the barn for firing with charcoal briquets the following year was little different from that used in making the barn ready for firing with coke.

Table 2. Labor used per acre in preparing the barn for curing Burley tobacco with artificial heat.

	Kind of fuel used					
	Coke		Charcoal briquets		Coke and charcoal briquets	
	1938	1939	1938	1939	1938	1939
Number of farms	54	29	9	15	5	13
Number reporting barn preparation	29	17	5	13	4	9
Number of barns prepared	83	29	9	15	5	13
Hours of labor, per acre	.4	.6	1.6	.6	.7	.7

Labor used in curing Burley tobacco with artificial heat averaged more for the farmers using coke than for those firing with charcoal briquets. (Table 3.) Starting fires, removing ashes, shining stoves and handling more fuel in firing with coke required additional labor. In a 10-day firing period each 5-acre barn of tobacco required, on the average three and one-half hours more labor when cured with coke than with charcoal briquets.

The coke fires were kindled outside the barn by using a quantity of rather heavy kindling. After a glowing bed of coals had formed

The stoves were placed in the barn and the coke was added. The charcoal briquet fires were started in holes in the barn floor by lighting a small amount of light kindling placed in each hole or by lighting kerosene which had been poured over a number of the briquets in the hole. In a few cases of both charcoal briquet and coke firing farmers saved time by starting the fires in the barn by lighting a small quantity of briquets that had been soaked in kerosene and placed in each stove. After a glowing bed of coals had formed, the coke was added.

Table 3. Labor used per acre in curing Burley tobacco with artificial heat.

	Kind of fuel used					
	Coke		Charcoal briquets		Coke and charcoal briquets	
	1938	1939	1938	1939	1938	1939
Number of farms	54	19	5	13	5	9
Number of barns	138	32	9	15	6	13
Average number of days in curing	12.2	8.0	8.6	7.2	18.1	11.0
Hours of labor, per acre	7.25	3.5	4.9	2.2	5.7	3.4

In 1938, a season of considerable rainfall during and following the curing period, the farmers did additional firing to dry the tobacco after it had been cured. The drying required one-half hour of labor per day for each acre of tobacco. (Table 4.) This was not necessary in 1939.

Table 4. Labor used in drying Burley tobacco with artificial heat, 1938.

	Kind of fuel used	
	Coke	Charcoal briquets
Number of farms	24	5
Number of barns	50	9
Average number of days in drying	4.1	4.4
Hours of labor, per acre	2.1	2.4

Total labor requirements were influenced by the length of firing which varied from one day to over 25 days. While the curing period averaged 12.2 days in 1938 and 8 days in 1939 for the barns fired with coke, a third of the farmers fired for about 10 days. The farmers using charcoal briquets averaged 8.7 days of firing in 1938 and 7.2 days in 1939, to cure the tobacco. Where a combination

of coke and charcoal briquets was used to cure the tobacco, the farmers, in general, used a slightly longer period in curing.

The firing period of the farmers using coke very probably was the more usual length of time required in curing Burley tobacco with artificial heat. Many of the farmers using a combination of coke and charcoal briquets, cured for a longer period because of the failure of an area of the barn to cure out properly. In several cases the charcoal briquet fires were started in sections of the barn where the tobacco had been hung too low to allow firing with the coke stoves. Many of the farmers using charcoal briquets fired for a shorter period because the fuel was new (they were giving it a trial) and costly in comparison with coke and because the heat was uniformly distributed over the entire barn. The uniform distribution of heat was made possible by having a number of small fires placed at intervals of 8 to 10 feet over the entire barn floor. The uniform upward movement of warm air over the entire barn undoubtedly, was a large factor in making possible the shorter curing period for the barns cured with charcoal briquets. The entire barn was cured out at the same time and the continuing of the fire under portions of the barn where the circulation of air had been improper to carry off the moisture was avoided.

The frequency with which the fires had to be refueled and the ashes removed influenced the amount of labor used in curing tobacco with artificial heat. Frequency of tending the fires was influenced in turn by the kind of fuel and stove used. Home-made stoves fired with coke were tended, on the average, more often than either manufactured stoves or charcoal briquet fires. Also, charcoal briquet fires were tended less often than coke fires in manufactured stoves.

Stove Requirements and Costs. Metal oil barrels, 10-gallon grease cans and discarded cans used by ice plants in the manufacture of block ice were the common materials out of which home-made stoves were made. Farmers who used the home-made stoves had an average of about 1.9 stoves for each acre of tobacco cured with artificial heat. Manufactured stoves were used by most of the farmers in this study who fired with coke. About 1.5 manufactured stoves were used for each acre of tobacco cured. The stoves were usually purchased by the landlord. Three-fourth of the landlords of 49 farms where the tobacco was raised by tenants purchased

the stoves. On the remaining farms the tenants purchased half the stoves.

The depreciation (purchased price divided by the estimated years that the stoves can be used) averaged 74 cents and 90 cents per stove, per year, for the manufactured stoves, in 1938 and 1939, respectively, and 39 cents and 35 cents per stove, per year, for the home-made stoves. (Table 5.) Since between one and two stoves were used for each acre of tobacco cured with artificial heat, the depreciation averaged about 68 cents per acre for home-made stoves and \$1.22 per acre for manufactured stoves for both years, 1938 and 1939.

Table 5. Number, value, life, depreciation and fuel used per coke stove, and stove depreciation per acre of tobacco cured with artificial heat.

	Home-made stoves		Manufactured-stoves	
	1938	1939	1938	1939
Number of stoves	123	85	1041	231
Value, per stove, dollars	1.62	1.32	7.52	7.36
Number, per acre	1.9	1.8	1.5	1.4
Pounds of coke used, per stove per day	64	140 ¹	52	52
Years of use, per stove	4.1	3.8	10.2	8.2
Depreciation, dollars				
Per stove	0.39	0.35	0.74	0.90
Per acre of tobacco	0.74	0.62	1.13	1.30

¹ This group included only 6 barns. For 2 of these barns an unusually large amount of coke was used. An average of about 75 pounds of coke was used per stove per day in 3 barns.

The home-made stoves used more fuel and required more frequent firing than the manufactured stoves, which offset the lower depreciation cost of the home-made stoves. Individual records indicated that the home-made stoves used, on the average, 20 to 25 pounds more fuel for each day of firing than the manufactured stoves. Where five days or more of firing were done per year the manufactured stoves saved enough fuel to equal or more than equal the higher depreciation on them.

Barn Requirements and Costs. Curing Burley tobacco with artificial heat reduced the amount of barn space used to house the tobacco. Space was conserved by hanging more stalks per stick and more sticks per tier-rail. On the other hand, space was lost by having to leave out a few rails of tobacco to provide space for the stoves. Charcoal briquet fires required less space than coke fires.

In 208 barns of tobacco cured with artificial heat, an average of 21 stalks of tobacco were hung per tier-rail. (Table 6.) In 37

barns of air-cured Burley tobacco 105 stalks were hung per tier-rail. Barns of tobacco cured with artificial heat contained 15 per cent more tobacco per tier-rail than barns with air-cured tobacco. In the barns where coke stoves were used, about 10 percent of the tier-rails were left unfilled in order to have room for placing and tending the stoves and to avoid getting the lower tiers of tobacco too hot. Where charcoal briquets were used, about 5 percent of the tier rails were left unfilled. Thus the barns fired with coke stoves housed about 5 per cent more tobacco than the barns with air-cured tobacco and the barns fired with charcoal briquets housed about 10 per cent more.

Table 6. Number of sticks and stalks of Burley tobacco per tier rail in curing with artificial heat and in air curing.

Length of rail	Tobacco cured with artificial heat			Tobacco air cured		
	Barns	Sticks per rail	Stalks per rail	Barns	Sticks per rail	Stalks per rail
feet	number	number	number	number	number	number
10	7	16	97	2	16	96
12	143	19	119	32	17	104
14	56	23	128	2	19	114
16	2	32	192	1	24	144

The cost of curing tobacco with artificial heat was offset to some extent by housing more tobacco in a given space when fire-cured than when air-cured. As shown in Kentucky Agricultural Experiment Station Bulletin 383 the normal housing cost for burley tobacco was \$16.00 per acre per year. This figure corresponded closely with that shown by a study made in 1932 in which housing and stick costs averaged \$16.25 per acre annually. Based on the space saved by firing with coke in stoves, 80 cents per acre was saved annually in housing costs and by firing with charcoal briquets \$1.00 per acre.

In actual practice an immediate reduction in housing costs resulted only in cases of insufficient barn space for air curing tobacco. On farms where reduction of tobacco acreage decreased the amount of tobacco to be housed as much, or more than, settling the plants closer increased it, curing with artificial heat did not reduce the housing costs. On farms where additional barn space was required immediately to house the tobacco adequately, under air-curing conditions, curing with artificial heat made it unnecessary to build additional barns and therefore reduced or avoided the

added costs for housing the tobacco. In the long run, as the barns become adjusted to the amount of tobacco produced under fire-curing conditions, the building cost is reduced.

Curing and Drying Cost. Fuel was the largest item of cost and labor was second in curing and drying Burley tobacco with artificial heat. Fuel was entirely a cash expense while labor was only a cash expense on farms where there was not enough family labor to carry on all the farm operations during the tobacco-curing season. Because of variations in the length of the firing and curing periods the total cost varied from year to year. The longer firing and curing periods entailed lower costs per day. In curing, the fires were kept burning slowly for the first few days, then more intensively for a few days and then allowed to taper off for a number of days. For drying the tobacco the fires were kept burning slowly during periods of damp weather.

The total cost of fuel, labor and depreciation on stoves in curing Burley tobacco with artificial heat was 56 cents and 63 cents per day for each acre in 1938 and 1939, respectively, when coke was used as fuel. When firing was done to dry the tobacco, the per acre cost increased and the cost per day of each acre cured decreased. (Table 7.) For charcoal briquets the total cost of curing and drying was 56 cents per day for each acre of tobacco in 1938. The total cost of curing in 1939 was 53 cents per day for each acre of tobacco. Firing with coke required stoves which added an item of depreciation as expense that was avoided by using charcoal briquets. On the other hand, the high price of charcoal briquets made the fuel cost more than for coke.

Finally, the cost of firing with coke was not significantly different from that with charcoal briquets, in 1938 and 1939. A comparison of two five-acre barns indicates a total cost of \$27.00 per barn with charcoal briquets and \$28.00 with coke, during a 10-day firing period. Assuming an average yield of 900 pounds of tobacco per acre, the cost of curing and drying with artificial heat for the 10-day period averaged about three-fifths of a cent per pound.

The data for 1938 and 1939 represented two rather extreme years. By using an approximate average for the two years, the more usual fuel, labor and stove requirements have been calculated. (Table 8.)

Table 7. Costs of curing and drying Burley tobacco with coke, charcoal briquets and both coke and charcoal briquets.

	Coke			Charcoal briquets			Coke and Charcoal briquets		
	1938	1939		1938	1939		1938	1939	
Number of farms	30	19	24	5	13	9	4	9	
Days of firing									
Curing	12.9	8	11.6	8.6	7.2	11	17.8	11	
Drying	—	—	4.1	4.4	—	—	—	—	
Fuel cost, per acre, dollars									
Curing	4.43	2.90	3.99	3.64	3.27	3.83	5.72	3.83	
Drying	—	—	.69	1.86	—	—	—	—	
Total fuel cost	4.43	2.90	4.68	5.50	3.27	3.88	5.72	3.88	
Labor cost, per acre, dollars ²									
Preparation of barns	0.08	0.12	0.08	0.32	0.12	0.14	0.14	0.14	
Tending fires in curing ...	1.53	0.70	1.38	0.98	0.44	0.68	1.12	0.68	
Tending fires in drying ...	—	—	0.42	0.48	—	—	—	—	
Total labor costs	1.61	0.82	1.88	1.78	0.56	0.82	1.26	0.82	
Stove depreciation, per acre ³ ..	1.13	1.30	1.13	⁴	⁴	1.30	1.13	1.30	
Total cost, dollars									
Per acre	7.17	5.02	7.69	7.28	3.83	6.00	8.11	6.00	
Per day for each acre	.56	.63	.49	.56	.53	.55	.46	.55	

¹ Only 1 of the 32 farmers did any firing to dry the tobacco in 1939. ² Labor valued at 20 cents an hour. ³ Depreciation of manufactured stoves since most farmers used the manufactured stoves. ⁴ No stove used in firing with charcoal briquets.

Table 8. Fuel, labor and stove requirements per acre in curing Burley tobacco with artificial heat under usual weather conditions.

	Coke	Charcoal briquets
FIRING, days		
Curing	10	10
Drying	2	2
FUEL, pounds per acre		
Curing	850	250
Drying	150	50
Total fuel	1000	300
LABOR, hours per acre		
Preparation of barn	.5	1
Tending fires in curing	5.5	3.5
Tending fires in drying	2.0	2.0
Total labor	8.0	6.5
NUMBER OF STOVES, per acre	1.5	—

FIRING PRACTICES

As a result of following the field work on the curing of Burley tobacco by artificial heat in 1938, numerous additional questions and the problem were raised by growers for whose tobacco crops had been secured. These formed the basis for an expansion of the study of practices connected with curing by the use of artificial heat.

Two-thirds of the farmers interviewed on these additional questions considered the use of artificial heat a practice to be followed every year rather than simply an emergency practice to be used only under adverse weather conditions. All of these growers indicated that loss from houseburning can be prevented by properly housing and firing the crop.

Two-thirds of the growers expressed the belief that the color of cured tobacco was improved by the use of artificial heat in firing. The inquiry brought out the further point that too hot firing during the first few days of the curing period resulted in losing the green color in the leaves. Frequently, mention was made of mottled, greenish-yellow coloring or "papawing" caused by too much heat where the stove was placed too near the tobacco.

As to the influence of firing upon the weight of the cured tobacco, two-thirds of the farmers stated that curing with artificial heat did not change the weight. About a third of the growers stated that the use of artificial heat in curing prevented weight loss by preventing houseburning. A third of the farmers stated that an

actual loss in weight occurred if the heat from the fires was too high for a considerable time.

As to whether the curing by artificial heat made it more difficult for the tobacco to come into case, two-thirds of the growers had not noticed tobacco cured with artificial heat come into case less readily than the air-cured leaf. One-fifth of the farmers thought that they had noticed fire-cured tobacco come into case less readily.

As to a greater tendency of Burley tobacco cured with artificial heat to damage when bulked, four-fifths of the growers had not noticed any greater tendency to damage because of the use of artificial heat in curing. A few said that tobacco cured with artificial heat damaged less rapidly in the bulk than the air-cured tobacco.

Practically all growers agreed that having the tobacco well ripened before housing reduced the amount of firing needed. At the same time they pointed out the impracticability of allowing the entire crop to ripen before starting to house, because of the increased risk of damage to the tobacco from unfavorable weather at the time of curing and housing.

Two-thirds of the growers preferred to allow the tobacco to wait for two or three days in dry weather before starting the fires for artificial curing. About one-half of the growers preferred to start the fires the same day the tobacco was housed if the weather was damp or the tobacco was rained on after it was cut.

As to methods followed in controlling the intensity of firing, a few more than half the farmers preferred slow fires for the first two or three days after the firing was started. Some of them thought it advisable to fire intensely during the first few days if the tobacco was well ripened or if the weather was damp. Many mentioned tapering off at the end of the firing period by reducing the number of stoves used.

Three-fifths of the farmers did not consider it necessary to keep the fires going continuously during the curing period. Two-fifths of them considered it advisable to fire continuously until the tobacco was cured, even in weather favorable for curing.

On the question of allowing the tobacco to hang in case after it was completely cured, more than a third of the growers allowed the cured tobacco to remain in case only one day before starting the fires to dry it; one-sixth of them started the fires on the third

y; a few waited until the fourth day and almost a third of them did not use fire to dry the cured tobacco.

As to whether cured tobacco is darkened by using artificial heat drying, three-fifths of the growers said that the tobacco was not darkened by drying with artificial heat; one fifth said it was darkened and another fifth expressed no opinion on the question.

All the growers agreed that uncured tobacco should not be hung under cured tobacco, but most of them found it impractical to avoid doing so. Many growers suggested that each bent be completely filled before starting to hang in the adjoining bent, thereby avoiding as much as possible having uncured tobacco placed under cured tobacco.

As to the number of fires used per bent of a barn 40 to 44 feet wide, where coke stoves were used, three-fifths of the farmers used one stove per bent; one-fifth considered two stoves necessary while another fifth preferred three stoves per bent. For firing with charcoal briquets two-fifths of the farmers considered three fires per bent enough while an equal number preferred four; another fifth thought it necessary to have five or even more fires per bent. Many using coke or charcoal suggested that the larger number of fires made possible a more even distribution of heat, which created better circulation of air thruout the entire barn to carry off the moisture.

As to the practice of shifting the location of the stoves in the barns during the curing period, about three-fifths of the growers did not shift the stoves. A considerable number shifted them in order to create a circulation of warm air in all parts of the barn, thereby making it possible to avoid the need of purchasing additional stoves.

As to the use of the doors to control ventilation during curing with artificial heat, about two-thirds of the growers kept the side and end doors closed during damp weather, while in dry weather the doors were opened during the day. In unusually dry weather some of the growers opened the doors at night and closed them during the day. About nine-tenths of the growers preferred top ventilation.

Growers generally stressed the point that curing Burley tobacco with artificial heat must be done with great care. Allowing the tobacco to yellow for a few days after housing, firing slowly the first few days, avoiding too intense heat on it by having enough space

between the stove and the tobacco, opening the doors and ventilators to allow an outward movement of the moist air and placing the fires so that a circulation of warm air reached all parts of the barn were considered important practices in proper firing. On the other hand, they stressed the point that more damage was done by improper use of artificial heat in curing than by air curing even under adverse weather conditions. Proper curing with artificial heat, however, reduced or prevented loss from houseburning during adverse weather and was helpful even during weather favorable for air curing.

SUMMARY

In recent years an increasing number of farmers have used artificial heat each year in curing Burley tobacco as a means of producing a lighter-colored, better-quality and higher-priced tobacco and also as a means of reducing damage from houseburning, especially when the tobacco is overcrowded in the barn.

Fuel, labor and stoves were the chief items of cost in curing with artificial heat. Coke and charcoal briquets were the principal fuels used. In 1938, fifty-four farmers used an average of 86 pounds of coke per day for each acre of tobacco cured with artificial heat during a period of 12.2 days. Twenty-four of these farmers, during a drying period of 4.1 days in 1938, used 42 pounds of coke per day for each acre of tobacco dried. In an 8 day period in 1939, 19 farmers used an average of 90 pounds of coke per day for each acre of tobacco cured.

Five farmers used an average of 24 pounds of charcoal briquets per day for each acre of tobacco during an 8.6 day curing period in 1938. A similar amount per day was used during a 4.4 day drying period. Thirteen farmers used an average of 24 pounds of charcoal briquets per day for each acre of tobacco cured with artificial heat in 1939.

Labor in preparing the barns for firing and tending the fires in curing and drying tobacco with artificial heat averaged 9.1 hours per acre in 1938 and 4.1 hours per acre in 1939 for the farmers using coke. The labor in curing with charcoal briquets averaged 8.9 hours per acre in 1938 and 2.8 hours in 1939.

Depreciation on home-made stoves averaged 68 cents per acre annually when approximately 1.9 stoves were used for each acre

tobacco fire cured. Manufactured stoves depreciated approximately \$2 per acre annually when 1.5 stoves were used per acre.

The total cost of coke, labor and depreciation on stoves averaged \$7.17 and \$5.02 per acre of tobacco cured with artificial heat in 1938 and 1939, respectively, or 56 and 63 cents per day, respectively, for each acre. The total cost of curing and drying with artificial heat averaged \$7.69 per acre or 49 cents per day for each acre in 1938. Charcoal briquets and labor cost \$7.28 per acre or 46 cents per day for each acre of tobacco cured and dried in 1938. In 1939 the cost was \$3.83 per acre or 53 cents per day for each acre cured.

By using coke in curing tobacco with artificial heat, about 5 percent more tobacco was housed per barn than when air curing, and with charcoal briquets, about 10 percent more was housed per barn.

Farmers considered as important practices in proper curing of burley tobacco with artificial heat: (1) allowing the tobacco to grow a few days before starting the fires; (2) firing slowly the first 3 days after starting the fires; (3) avoiding too intense heat by leaving enough space between stoves and tobacco; (4) opening doors and ventilators to allow an outward movement of moist air, and replacing the fires so that a circulation of warm air reached all corners of the barn.

Kentucky Agricultural Experiment Station

University of Kentucky

THE EFFECT OF TEMPERATURE AND RELATIVE
HUMIDITY DURING AND AFTER CURING, UPON
THE QUALITY OF WHITE BURLEY TOBACCO

BULLETIN NO. 407



Lexington, Ky.

July, 1940

(353)

CONTENTS

	Pa
Literature review	35
Methods	35
Experiments on curing tobacco	35
Rate of air movement	35
Splitting vs. tying	36
Fifty percent vs. eighty-three percent relative humidity	36
Sixty percent vs. seventy-seven percent relative humidity ..	36
Constant 68 percent relative humidity vs. higher followed by lower	36
Constant conditions vs. diurnal fluctuation	36
Minimum temperature for curing	36
Experiments on cured tobacco	37
Deterioration of cured tobacco	37
Moisture content of cured tobacco	37
Discussion	37
Plans for future work	38
Summary	38
Literature cited	38

THE EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY DURING AND AFTER CURING, UPON THE QUALITY OF WHITE BURLEY TOBACCO

By R. N. JEFFREY*

This bulletin is a progress report on certain phases of a series of studies being conducted at the Kentucky Agricultural Experiment Station on the curing of the types of tobacco grown in this State. It is particularly concerned with the effect of temperature and relative humidity during curing, on the quality of cured Burley tobacco. The work herein described was begun in 1936 and has been in progress continuously since that time.

LITERATURE REVIEW

The curing of tobacco has been a subject of interest and discussion for many years but the amount of carefully controlled experimentation has been relatively small because of the difficulty and expense of a thorough investigation of this problem. The workers in the field have long recognized the desirability of such study. Much has been written based upon observation in barns, but accurate control of conditions has not been possible because of lack of equipment. Garner (4) stated long ago, on the basis of his observations, that the favorable temperatures for curing cigar tobacco were between 60° and 100°F and the optimum relative humidity about 85 percent. Apparently it has been assumed that this optimum applied to other air-cured types including Burley.

In 1928 Johnson (5) described chambers 4 x 4 x 4 feet in which temperature and humidity were controlled and in which he subsequently (6) conducted experiments upon the curing of Wisconsin tobacco. He used three such chambers, but since the fan and recording equipment were all inside the chambers, the space left for tobacco was rather small. Johnson reported all of his quantitative results as percent loss in weight of the tobacco rather than in terms of quality of the cured product, so the reason for his conclusion that the numerical value of the temperature in degrees Fahrenheit and of the percent of relative humidity should be the same is not obvious from the data. In the same paper (6) in the section on

*The writer wishes to express his appreciation to Mr. Hugh Taylor, of the Bureau of Agricultural Economics, U.S.D.A., and to Prof. E. J. Kinney, Mr. Russell Hunt, Prof. O'Bannon, Mr. Claude Rankin, Dr. W. D. Valleau, and Mr. Earl E. Young, of the Kentucky Agricultural Experiment Station, for assistance and advice on this project.

chamber studies (pages 15-16), it is stated: "At a temperature of 95°F, with a relative humidity maintained at approximately 95% an almost ideal cure was obtained" and in the section on barn experiments (page 29): "All things considered, the most pressing problem of moisture relations in curing is largely one of lowering the humidity during critical periods when danger of damage from 'shed-burn' or 'pole-rot' occurs. Serious danger usually does not arise unless two or four consecutive days with a relative humidity of 95 to 100% occur during a time when the curing leaf is in a stage susceptible to damage. Since such high humidities rarely continue for several days at a time without interruption, it may be roughly estimated that the humidity is excessive only when it exceeds a weekly average of 85% in our data." These two statements appear to be contradictory.

Two chambers similar to those used by Johnson were installed at the Tobacco Substation of the Connecticut Agricultural Experiment Station at Windsor, in 1929, and were used for several years. The Connecticut workers reported in 1931 (8) that 80-85 percent relative humidity was the best at most temperatures for cigar tobacco and that humidities below 70 and above 90 percent were inadvisable, without regard to temperature. They recommended in a later paper (1) 70-80 percent relative humidity at 90°F and 80-85 percent at 95°F. They state that they were unable to obtain humidities sufficiently low for satisfactory curing at 80°F. Their results indicate a higher optimum humidity at higher temperature, as did those of Johnson, but the humidities recommended are lower. From a later paper describing experiments in curing barn (9) it is evident that the average humidity maintained, even in their humidified barn (figure 138), was below 70 percent and in their unhumidified barn still lower, but no difference in the commercial value of the tobacco obtained was demonstrable.*

A paper by Cooper and associates (3) at Virginia Polytechnic Institute, on the use of conditioned air in curing flue-cured tobacco

* After this paper was prepared a more recent paper from the Connecticut Station came to our attention (P. J. Anderson, Diseases and Decays of Connecticut Tobacco, Conn. Agr. Expt. Sta. Bull. 432: 158-161. 1940.). In the text of that paper it is stated that in Connecticut Shade tobacco it has been found that the best colors and qualities are produced by keeping the humidity percentage about 10 points below the temperature. However, a figure is included (figure 35) in which the zone of best curing conditions is bounded by the temperatures of 65° and 95° and by wet bulb depression corresponding to about 77% relative humidity at 95° and 55% at 65° as an upper humidity limit and by about 48% at 95° and 41% at 65° as a lower limit. If a "points below" line is plotted on this chart corresponding to the series of conditions recommended in the text, about half of the line falls outside the optimum zone of the figure, and the rest in the extreme edge of this zone. The statement made elsewhere in this bulletin that the optimum humidity for curing Burley is lower than that which has been recommended for cigar tobacco, does not apply to this paper.

appeared recently. Like Johnson, Cooper expressed all quantitative data in terms of drying rates, not quality of the cured product but, like the previous workers, he apparently advocates the use of an air-conditioning system in practical curing. He states that the minimum relative humidity during the yellowing stage of a little over one day is 80-85 percent but does not state how this value was obtained. It is rather difficult to see how this information could have been obtained with certainty in the one chamber at Dr. Cooper's disposal. He states that the humidity at later stages of flue curing should be lower, but does not make definite recommendations.

METHODS

The equipment that made this investigation possible was designed by Professor L. S. O'Bannon of the Kentucky Agricultural Experiment Station, who also supervised its installation and assisted in the operation of the equipment until the present author became familiar with the complicated apparatus. This equipment has been described by O'Bannon (7) in some detail; consequently it is not necessary to give a complete description here. However, it may be stated that the equipment includes nine curing chambers, each 10 by 5 feet in plan dimensions. Three of these chambers are 10 feet high and hold two tiers of tobacco and the remaining six are about 5 feet high and hold one tier of tobacco. Conditioned air is admitted at the bottom of each chamber and passes upward through the chamber and out at the top. The average rate of air movement in the chambers in all experiments except where otherwise specified, was 15 linear feet per minute. The wet-bulb and dry-bulb temperatures are measured with recording and controlling thermometers in the insulated outlet duct. The relative humidity can be calculated from these records. Temperature can be maintained at any value between about 50°F and 150°F and relative humidity at any value between about 25 percent and 95 percent. The variation in temperature from the desired value during the cycles characteristic of automatic control systems depends upon the condition maintained with respect to outside conditions and upon the various adjustments of the equipment, and may be as much as $\pm 2^\circ\text{F}$ but is usually less than $\pm 1^\circ\text{F}$. The average temperature maintained is much closer to the desired value; usually within 0.5°F . The relative humidity is controlled by means of a wet bulb and since this may have a different cycle period from

the dry bulb control, the momentary fluctuations sometimes exceed 5 percent relative humidity but the average values over long periods are less than that if the equipment is properly maintained and kept in calibration. The equipment outside the chambers includes hot and cold water and steam sprays, a silica gel dehumidifier, refrigeration, steam and electric heating equipment, circulating fans on each chamber and on the central system which supplies the conditioned air. The control system operates mainly by moving dampers which regulate the proportion of warm and cold and moist and dry air reaching each chamber. Each tier rail in the chambers is suspended from a scale in order that the rate of loss of weight of the tobacco may be followed during curing. The weight is determined at least once a day and oftener if necessary. Each tier is normally occupied by six sticks of tobacco, spaced about 9 inches on centers, with six plants per stick. This gives about the same spacing as would be obtained with 15 sticks on a 12-foot tier rail. The smaller chambers hold 36 plants and the larger ones 90 plants. In all experiments here reported, Kentucky Experiment Station No. 16 Burley tobacco was used. The method used in this typical experiment may be described as follows.

Before the tobacco is cut, each chamber is adjusted to the required temperature and humidity for the test which is contemplated and the tare weight of the sticks and tier rails is determined. The tobacco is cut, by whatever method is required, and each stick of tobacco is weighed immediately. One stick is cut for each tier rail in each chamber and then a second stick for each and so on to eliminate as far as possible variation between samples due to soil or other conditions in the field. After the tobacco has wilted in the field, either in piles or on a scaffold, it is hauled to the curing laboratory where each stick is reweighed to determine the loss of weight in wilting and then hung in the proper chamber. The tobacco is examined at frequent intervals and notes are taken on the rate of yellowing and of browning or "coloring". In addition, loss of weight is recorded daily. After the cure is completed, the controllers of all chambers are set to 75°F dry bulb, and 70°F wet bulb corresponding to 78 percent relative humidity, which gives about the most satisfactory "case" at which to strip the tobacco to a uniform condition for weighing. When the tobacco is in case, each stick is weighed, stripped, and separated according to stripping room grades, and each of these is further separated according

kind of injury which may have occurred during curing. The classes used in this connection are (1) uninjured, (2) houseburned, (3) darkened but not houseburned, (4) stem rotted, (5) mottled, (6) called "papawed" or "piebald", and (6) green. In order to prevent injury previous to curing from affecting the results, an additional class (7) is recognized to include leaves injured by insects, disease or "ground injury" before cutting, or by sunburn or blighting during cutting and housing, as these injuries sometimes change the effect of curing conditions upon the leaf. The weight of each curing-injury class in each stripping-room grade is then determined, as well as the stalk weight. The percentage of weight of total cured leaf to the fresh field weight, and the percentage of each stripping-room grade and each curing-injury class to the total cured weight, exclusive of "injured before curing" class, is calculated. In all the more important tests the hands of tobacco graders in each chamber are placed consecutively on sticks, the "leavings" at one end and the "Tips" at the other. The different samples from a given cutting of tobacco are placed before at least six experienced tobacco graders working independently who are asked to state their order of preference without knowing the curing conditions. The cumulative graders' preference is obtained by adding together the figures indicating the position of each sample in the order of preference of each grader. The sample considered to be the first preference of the group is the one for which this sum is smallest, and this is indicated by a number 1 in the last column of tables 2, 3, 4, 5, and 7. The next smallest sum is indicated by a 2 in the graders' preference column, etc. When a given variable is being considered, it is assumed that the preference is for the sample bearing the lowest number, of those samples differing in this variable only.

EXPERIMENTS ON CURING TOBACCO

The experiments reported in this bulletin were conducted on field-grown tobacco. An equal number of preliminary experiments were conducted on greenhouse-grown tobacco, because the possible number of tests per season using field-grown tobacco is so limited. Some of the results obtained on greenhouse-grown tobacco contrast with those here presented.

Rate of Air Movement. The first experiment was conducted to determine whether the rate of air movement selected when the

chambers were designed was satisfactory for the proposed experiments. The three large chambers were operated at the same temperature and humidity but at different rates of air movement. The results are shown in table 1. The rate of loss of the first 50 percent of fresh weight was not significantly different in the different chambers. When the weight loss was plotted against time, the curves obtained followed each other closely throughout the experiment. The quality of the tobacco cured in the upper tier was significantly different in different chambers. However, the quality of the tobacco cured in the lower tier was distinctly poorer in the chambers where the rate of air movement was reduced. In the description of the apparatus, it was pointed out that the wet- and dry-bulb thermometers which operate the control equipment are in the exit duct. This is necessary in order to obtain sufficiently high air velocity around the wet bulb to give an accurate reading. The difference between the time at which the control begins to call for moisture, and the time at which the moisture reaches the control point, resulting in a call for dry air, is greater in a chamber operating at reduced air velocity than under normal conditions. Hence there is a longer cycle and one with much wider fluctuations of both temperature and humidity at low velocity, especially in the

Table 1. Effect of rate of air movement. Crop No. 4, cut and housed September 17, 1937.

Curing chamber	No. 1	No. 2	No. 3
Average temperature, degrees Fahrenheit	80	80	80
Average relative humidity, percent	63.2	64.0	63.2
Rate of movement of air, linear ft. per min. ..	15	10	5
Wilted tobacco as percent of field weight	97.1	97.3	97.1
Time required to lose $\frac{1}{2}$ the field weight, days	4.2	4.8	4.2
Yield of cured leaf, as percent of field wt.	8.5	9.4	8.5
Quality of the cured leaf			
in top tier	satisfac- tory	satisfac- tory	satis- to
in bottom tier	satisfac- tory	fair	po

lower part of the chamber where the air enters. Since the rate of drying was not significantly different at different rates of air movement, it seems probable that the poor quality of the tobacco in the lower tier of the low-velocity chambers resulted from the widely and rapidly fluctuating conditions and not directly as a result of the increased velocity. Therefore the use of an air velocity of 15 linear feet per minute can be assumed to be satisfactory for these experiments.

ents. This rate of air movement causes barely perceptible movement of the plant leaves.

Splitting vs. Tying. Evidence has been obtained in preliminary experiments that the initial rate of loss of weight of split tobacco was sometimes twice as great as that of speared tobacco, but the effect on the quality of the cured product was not known. In spearing tobacco the stalk is split open for 12 to 18 inches in the region of the most valuable leaves, whereas in split tobacco the split extends to the top of the plant. Consequently it has been felt that the effect of splitting the stalk could be determined most certainly by comparing plants which were not split at all, but tied to the sticks, with split tobacco. Consequently these two extremes of cutting and housing practice were used in all tests during the 1938 season. The tests conducted on all three crops included two temperatures, 90° and 75°F. They differed, however, in the humidities used.

Fifty Percent vs. Eighty-three Percent Relative Humidity. The 1938 field crop was cut August 5 while still somewhat immature, but no more so than many farm crops. The humidities selected for curing the crop were 50 percent and 83 percent. This made a total of four air conditions in the chambers: 90°F and 83 percent relative humidity; 90°F and 50 percent relative humidity; 75°F and 83 percent relative humidity; and 75°F and 50 percent relative

Table 2. Effect of 50 percent vs. 83 percent relative humidity at 75° and 90° F, with split and tied tobacco. Crop 7, cut early in the season, August 5, 1938, when somewhat immature. Raised on average soil.

Cutting practice	Temperature	Relative humidity	Time in curing chambers	Time to reach 50% of field wt.	Defects at stripping	Cumulative graders' preference
	°F	percent	days	days		
Split	75	50	27	4.6	Green, mottled	3
Tied	75	50	27	7.4	Mottled	1
Split	75	83	27	10.0	Considerably darkened	6
Tied	75	83	27	14.3	Worse than above	8
Split	90	49	27	2.9	More mottled than 1st sample	4
Tied	90	49	27	4.5	More mottled than 2nd sample	2
Split	90	83	14			
	90	74	13	5.3	Badly darkened	7
Tied	90	82	14			
	90	73	13	8.1	Badly darkened	5

humidity, with both split and tied tobacco in each condition. Since it became obvious before the crop was cured that the high temperature-high humidity samples would be injured very seriously the humidity in this chamber was reduced after two weeks. Curves

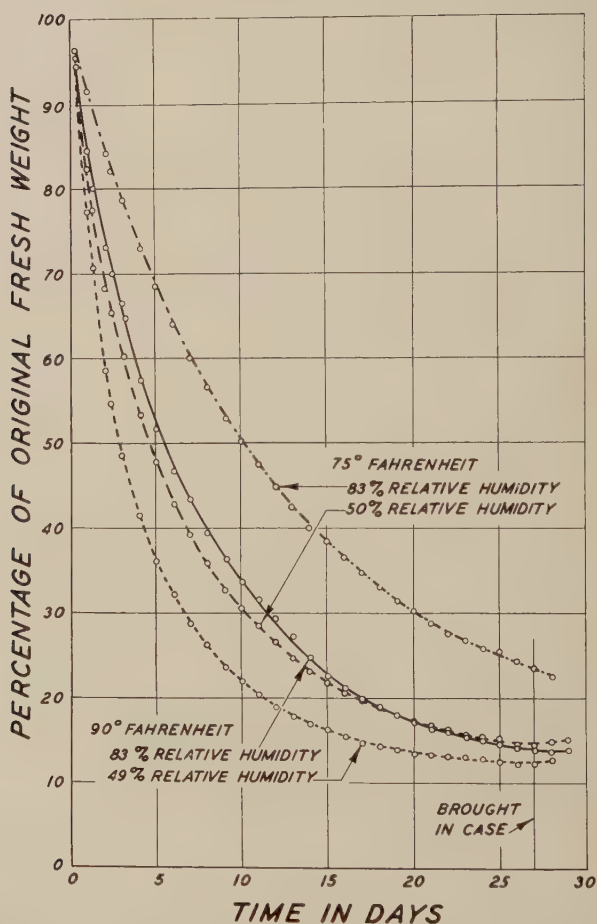


FIGURE 1. Rate of weight loss of split tobacco at different temperatures and relative humidities.

showing the rate of weight loss for split tobacco are presented in figure 1 and for tied tobacco in figure 2. Other results are shown in table 2.

It is evident from this table that the rate of loss of the first 50 percent of the weight was about two-thirds as great with the tied

alks as with the split stalks. The difference is even greater at an earlier stage and less at a later stage. There is no direct relation between the rate of weight loss and the final quality; neither is there evidence that the graders consistently favored either split or tied tobacco.

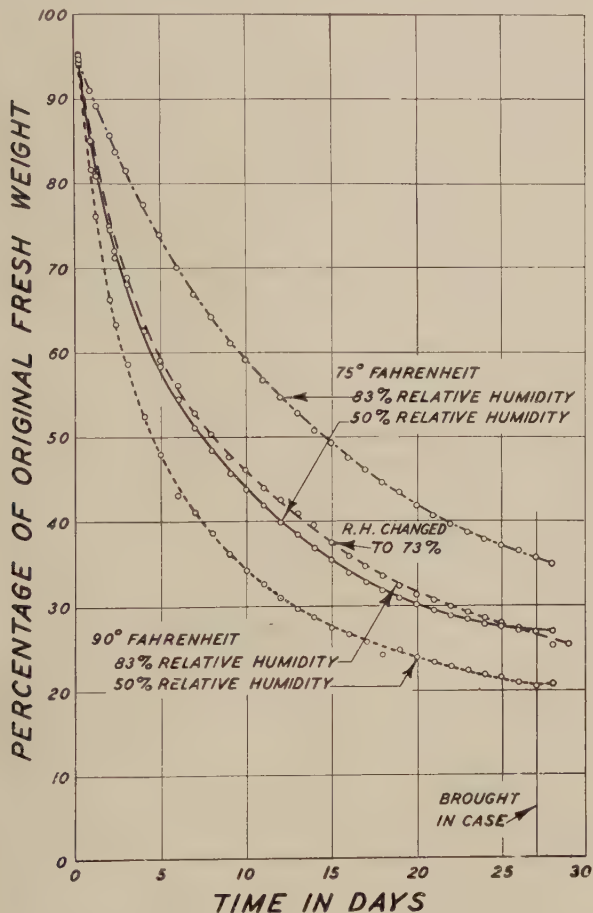


FIGURE 2. Rate of weight loss of tied tobacco at different temperatures and relative humidities.

On the other hand, if the graders' preferences are examined with respect to humidity as a variable, the preference of the group is unanimous for the samples cured at a relative humidity of about 50 percent as compared with corresponding samples cured at a relative humidity of about 83 percent.

This indicates definitely that the optimum relative humidity for curing Burley and cigar tobaccos is not the same. Tobacco cured at 83 percent relative humidity was all badly darkened and in some cases approached typical houseburn, whereas the 50 percent relative humidity samples were much lighter in color but mottled and a few leaves showed green. The reason for the grader's preference for the latter samples was the distinct commercial preference for Burley of light color. The record of curing injury shows that 50 percent relative humidity is below the optimum for Burley tobacco, tho it is decidedly preferable to 83 percent. Records obtained at the time of stripping indicate that the split tobacco cured at low humidity was injured more by the rapid drying than was the tied tobacco. No significant preference was shown between tobacco cured at 75° and that cured at 90°F, either by the group or by individual graders.

Sixty Percent vs. Seventy-seven Percent Relative Humidity

Since the optimum relative humidity appeared to be between those used in the preceding experiment, the conditions used for the second 1938 field crop duplicated those of the first except that the two relative humidities were closer together. About 60 percent and 77 percent relative humidities were selected for the second experiment instead of 50 percent and 83 percent used in the first. The results of the second test are shown in table 3. Similar conclusions to those of the previous experiment can be drawn; namely,

1. There is no direct relationship between the rate of weight loss and the quality of the cured tobacco.

Table 3. Effect of 60 percent vs. 77 percent relative humidity at 75° and 90°F, with split and tied tobacco. Crop 8, cut at mid season, September 6, 1938, when fully mature. Raised on good soil.

Cutting practice	Temperature	Relative humidity	Time in curing chambers.	Time to reach 50% of field wt.	Defects at stripping	Cumulative graders' preference
	°F	percent	days	days		
Split	75	62	28	5.0	Mottled	1
Tied	75	62	28	9.1	Same	4
Split	75	77	28	8.4	Darkened and)	6
Tied	75	77	28	13.2	moldy stems) Same	8
Split	90	59	28	3.6	More mottled)	2
Tied	90	59	28	6.4	than 1st sample) Same	3
Split	90	77	28	5.4	Darkened	7
Tied	90	78	28	8.6	Same	5

2. There appears to be a preference for split tobacco in this experiment, but it cannot be considered significant, as it was not confirmed in the other similar experiments.

3. There is no consistent preference for either 75°F or 90°F as a curing temperature.

4. There is a preference for 60 percent relative humidity over 77 percent. The graders were unanimous in this preference.

5. The 77 percent relative humidity samples were darkened, indicating too slow drying, and the 60 percent relative humidity samples were mottled, indicating too rapid drying; thus the optimum relative humidity lies between these values.

Constant 68 Percent Relative Humidity vs. Higher Followed by Lower. Since the optimum relative humidity was obviously between the limits of 60 percent and 77 percent, it seemed that 68 percent should be about the right value. Growers often make the statement that the tobacco should be kept more moist during yellowing than at a later stage so a constant relative humidity of 68 percent was compared in the next experiment with a humidity of 77 percent during yellowing followed by a lower value. This experiment was conducted upon 1938 late-season, over-mature tobacco. The results are shown in table 4. In this experiment the graders' preference favored tied tobacco. Of the three experiments involving this variable, one showed no preference, one showed

Table 4. Effect of constant 68 percent relative humidity vs. higher followed by lower at 75° and 90°F, with split and tied tobacco. Crop 9, 1938, October 10, 1938, when over mature and late in season. Badly injured by insects. Grown on good soil.

Cutting practice	Temperature	Relative humidity	Time in curing chambers	Time to reach 50% of field wt.	Defects at stripping	Cumulative graders' preference
	°F	percent	days	days		
Split	75	68	25	4.4	Slightly mottled	2.5
Tied	75	68	25	8.8	Slightly mottled	2.5
Split	75	77	14			
	75	60	11	8.8	Somewhat darkened	5
Tied	75	77	14			
	75	60	11	12.6	Somewhat darkened	4
Split	90	68	25	4.2	Slightly mottled	7
Tied	90	68	25	7.8	Slightly mottled	1
Split	90	77	7			
	90	50	18	4.4	Considerably darkened	6
Tied	90	77	7			
	90	50	18	8.6	Considerably darkened	8

some preference for split and one approximately equal preference for tied, so no significant difference can be claimed. There was a tendency toward preference for the lower temperature in this experiment, tho the first choice was a high-temperature sample. In respect to relative humidity the graders' preference favored the constant 68 percent relative humidity over the initial 77 percent followed by a low relative humidity but there was one instance where this was not the case. The split 90°, 68 percent sample fell in seventh position in order of preference, whereas the split 90°, 77 percent followed by 50 percent sample fell in sixth position. When the individual grader's preferences are considered, two favored the one sample and two the other. Since of the 90° tied samples the 68 percent sample was first and the other last choice, and both of the 68 percent samples were preferred at 75°F, it can be concluded that there is no advantage in the use of a relative humidity as high as 77 percent for as long as a week or two. This does not preclude the possibility of high humidity being desirable for a shorter time.

Constant Conditions vs. Diurnal Fluctuation. The question naturally arises as to whether the results as to optimum temperature and relative humidity obtained at constant conditions are comparable with those obtainable under barn conditions, where the temperature rises in the daytime and falls at night and the relative humidity falls in the daytime and rises at night. During cloudy weather the variation between day and night conditions is relatively small, but during clear weather it is considerable. The temperature and humidity records obtained in a barn on the Station farm during a period of good, clear curing weather between August 25 and September 3, 1938, were averaged by two-hour intervals. The average temperatures outdoors and at two locations in the barn are presented in figure 3 and the average humidities at the same locations in figure 4. It can be seen from figures 3 and 4 that a typical condition in the barn is that in which the temperature is about 10°F higher and the humidity about 20 percent lower in the daytime than at night. The absolute humidity or dew point temperature remains about the same day and night. It is impractical to attempt to reproduce exactly these gradual changes in the chambers, but it is sufficiently accurate to operate during a 9-hour period in the daytime at one condition and during a 15-hour period at night at another condition.

By the time the following experiment was conducted on an early 1939 crop, all nine chambers were completed, which made possible the simultaneous investigation of three different levels of

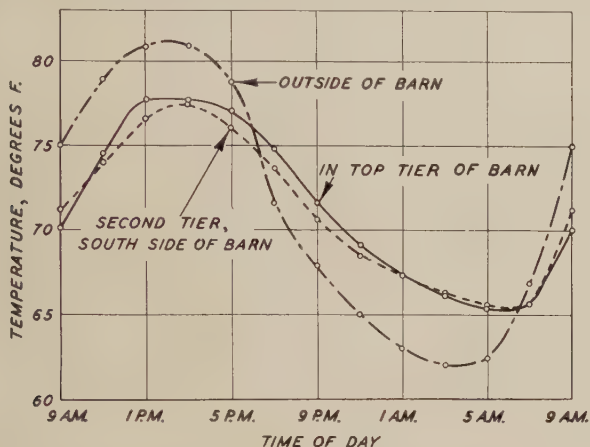


FIGURE 3. Average temperature outside and inside a full Burley tobacco barn during good curing weather at Lexington, September 25 to October 3, 1938.

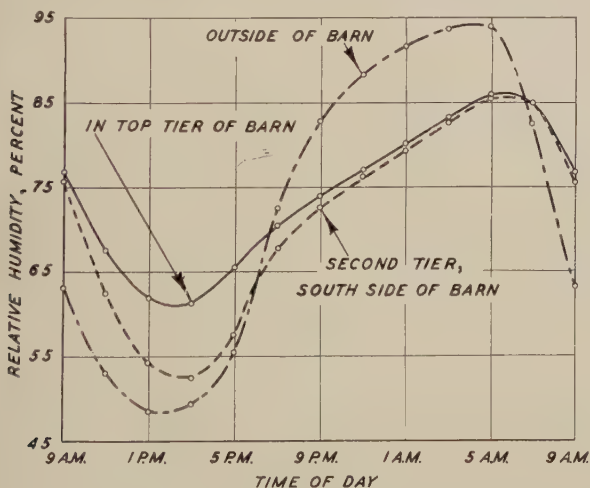


FIGURE 4. Average relative humidity outside and inside a full Burley tobacco barn during good curing weather at Lexington, September 25 to October 3, 1938.

to variables. One variable was the degree of diurnal fluctuation. Three chambers were operated at constant conditions. It was planned to operate three more with a variation of about 15 percent relative humidity between day and night conditions, a little less than

that shown in figure 4. The remaining three chambers were to be operated with a variation of 30 percent relative humidity between day and night conditions, or more than that shown in figure 4. An outline of the conditions in each chamber is shown in table 5. Chambers Nos. 1, 2, and 3 were operated at constant conditions with relative humidities (1) a little above the optimum obtained in the previous year's experiments; (2) at the optimum and (3) below the optimum. The next three chambers were to be operated with No. 4 at the same *average* relative humidity and the same dew-point temperature as No. 1; No. 5 the same *average* as No. 2, and No. 6 the same *average* as No. 3, but with a variation between day and night conditions of 15 percent relative humidity but no variation in dew-point temperature. Similarly the last three chambers were to be operated at the same *average* relative humidities, respectively but with 30 percent difference between day and night relative humidities and no difference in dew-point temperatures. The average dry-bulb temperature in all cases was as near 75°F as possible. Some tobacco was also hung in the curing-chamber room to compare with the chamber tobacco. Under the heading "Conditions obtained" in table 5 are shown the conditions actually obtained.*

The graders' preferences are presented in a form in which they are more readily interpretable in table 6. The relative humidities

Table 5. Effect of constant conditions vs. diurnal fluctuation at different average relative humidities. Crop 11, cut July 31, 1939, from somewhat immature tobacco early in the season. Raised on good soil.

Cham- ber	Conditions obtained						Defects at strip- ping	Cumulative graders' preference
	Day		Night		Average			
	Temp- era- ture	Relative humidity	Temp- era- ture	Relative humidity	Temp- era- ture	Relative humidity		
	°F	percent	°F	percent	°F	percent		
1					75.1	60.0	Mottled green on immature leaves	6
2					75.2	67.8	Slightly mottled	3
3					75.4	73.0	Slightly mottled	5
4	81.4	51.2	72.6	69.6	75.6	63.4	Mottled	7
5	79.9	49.7	73.1	77.6	75.4	68.1	Slightly mottled	1
6	80.6	59.2	75.7	76.0	77.4	70.3	Slightly mottled	2
7	85.7	39.6	70.9	65.0	75.9	56.4	Mottled	4
8	84.8	42.4	70.8	69.9	75.5	60.5	Mottled and green	9
9	84.4	58.0	72.5	85.2	76.5	75.9	Mottled	8
Room	—	—	—	—	—	—	Badly mottled	10

*After this experiment was completed a change was made in the wet-bulb assembly to make the recorder-controller respond more quickly to variations in wet-bulb temperature so that better results can be obtained in the future on experiments of this type.

grouped according to the values actually obtained, as are the different degrees of diurnal fluctuation. Since chamber 8 actually fluctuated more than planned, the corresponding graders' preference (1) is placed in the fourth column instead of the third. Similarly the average relative humidity in chamber 8 was lower than planned and so falls in the low group instead of the medium group; therefore the corresponding graders' preference (9) is placed with the low group. This experiment confirms the results obtained with the 1938 crops as to the optimum relative humidity. It does not appear that the degree of diurnal fluctuation has any very marked effect on the optimum relative humidity. However, this type of experiment should be repeated with additional crops of tobacco and the water control now available.

Table 6. Effect of constant conditions vs. diurnal fluctuation upon the graders' preferences at different relative humidities. Crop 11, average temperature about 75°F.

Relative humidity	Constant	About 17% fluctuation	About 27% fluctuation
percent			
56 — 64	6	7	4, 9
67 — 68	3	—	1
70 — 76	5	2	8

Minimum Temperature for Curing. The results of the preceding experiments show that much of the injury to tobacco during curing ordinarily attributed to adverse temperature is really due to adverse relative humidity. At the same time it is obvious that there is a temperature below which it is not possible to cure tobacco properly even if the humidity is correct. The next experiment, using the second 1939 field crop, was designed to determine the lower temperature limit for curing. In order to take into account any variation in the optimum relative humidity at these lower temperatures, three humidities were used at each of the three temperatures, 55°, 65°, and 75°F. Some of the results are shown in table 7. The graders' preferences are presented in table 8 in a manner which makes the results more evident. All samples cured at 55°F had a greenish cast, with the largest amount of green at the lowest relative humidity. There was also a considerable amount of green in the low relative humidity sample at 65°F but none in the other samples. The 75° high humidity sample was darkened as before. The remaining samples were all very good;

Table 7. Minimum temperature for curing. Crop 12 cut August 1939, when mature. Grown on good soil.

Sample No.	Temperature	Relative humidity	Time to reach 50% of field wt.	Defects at stripping	Cumulative graders' preference
	°F.	percent	days		
1	55.7	55	10.1	Extensive green	10
2	55.7	64	12.1	" "	9
3	55.9	72	12.0	Green and mottled	8
4	65.1	57	8.3	Mottled and green	7
5	65.2	72	10.6	Somewhat mottled	1
6	65.1	75.5	12.6	Slightly darkened and mottled.	2.5
7	74.6	59	7.4	Mottled	2.5
8	75.1	70.5	12.0	"	4
9	75.0	78	12.0	Darkened	5
Room				Badly mottled	6

much better than the tobacco cut from the same field about the same time and cured in a barn.

From this experiment it may be concluded that a temperature of 55°F is too low for satisfactory curing of Burley tobacco, but that 65° is satisfactory if the humidity is not too low. Any effect which temperature may have on the optimum relative humidity is the reverse of that reported for cigar tobacco; that is, the humidity may be slightly higher when the temperature is low and lower when the temperature is high. This is a much easier situation to produce in practical barn curing than is the reverse recommended by investigators as a result of curing experiments with cigar tobacco.

Table 8. Minimum temperature for curing. Crop 12. Graders' preferences.

Relative humidity	55°F	65°F	75°F
percent			
55 — 59	10	7	2.5
64 — 72	9	1	4
72 — 78	8	2.5	5

An interesting point which may be discussed in connection with this experiment is the effect of temperature and humidity upon the rate of yellowing of the tobacco. So far no wholly satisfactory quantitative results have been obtained but estimates were made from time to time of the extent to which the green color disappeared. The variation between different plants, and between different parts of the same plant, was so great as to make the individual figures unreliable. However, it can be stated with certainty that the

of yellowing increases with temperature thruout the range investigated (55-90°F) and it also increases with decreasing relative humidity. An increase in rate of yellowing at higher temperatures is expected but the reason for an increase at lower humidities is not clear, but the fact has been observed in every experiment. Of course the extent of this increase in rate of yellowing with increased relative humidity is not as great as the increase in rate of drying, so there is more tendency for tobacco cured at low relative humidity to cure green than at higher humidity.

EXPERIMENTS ON CURED TOBACCO

C Deterioration of Cured Tobacco. The curing chambers are also being utilized to study the effect of air conditions after curing, but more stripping, on the quality of the tobacco. Tobacco which had been in barn cured was selected for uniformity, placed in the chambers, and subjected to various temperature and humidity conditions. An initial sample was kept dry as a standard for comparison. This is designated in table 9 as test 0. Sticks of tobacco were removed from the chambers from time to time to determine the rate of change. These samples were dried upon removal from the chamber to stop the changes which had been taking place. Temperatures of 55°, 65°, and 75°F were used, combined initially with relative humidities of about 70, 80 and 90 percent. In table 9 each of these combinations of conditions is designated as a test, with the sticks exposed in the chambers for various lengths of time. After the tobacco had been stripped and the hands placed on sticks as in the foregoing experiments, experienced graders were asked to estimate the value of this tobacco relative to the initial sample rated as test 0. The average values assigned by the graders are shown in the last column of table 9. A careful study of these data will show that the tendency was for the tobacco to first increase in value and then decrease. Because of the great difference in the rate of change under different conditions, few of the experiments show both the increase and the subsequent decrease, tho some, like tests 2, 7, and 11, do show both. The initial increase in value resulted from the fact that this 1939 barn-cured crop was mottled from too rapid curing at low relative humidity. Much of the 1939 crop of the state was similarly mottled. The color darkened somewhat under the influence of even the relatively low humidities but

Table 9. Changes in relative value of barn-cured tobacco when kept under controlled conditions in the curing chambers.

Test No.	Stick No.	Temperature	Relative humidity	Time	Relative value
		°F	percent	days	
0	0	65	dry	41	100
1	1	74.8	70	4	110.4
	2	"	"	18	108.0
2	1	"	78.5	4	105.8
	2	"	"	11	102.0
	3	"	"	18	104.8
	4	"	"	24	104.0
	5	"	"	36	102.2
	6	"	"	41	101.8
3	1	74.9	89	4	98.8
	2	"	"	6	97.0
	3	"	"	11	90.0
	4	"	"	18	75.0
	5	"	"	24	68.0
	6	"	"	40	54.0
4	1	55.5	85	4	100.0
	2	"	"	11	95.0
	3	"	"	18	85.0
	4	"	"	31	86.6
	5	"	"	40	77.0
6	1	54.6	81	11	98.0
	2	"	"	31	98.0
	3	"	"	40, 41	100.4
7	1	64.8	75.5	11	104.0
	2	"	"	24	102.4
	3	"	"	31	98.6
	4	"	"	40, 41	95.0
8	1	"	89	4	98.0
	2	"	"	11	94.0
	3	"	"	18	89.4
	4	"	"	24	84.4
	5	"	"	40	74.0
10	1	74.8	70	19	
		75.2	94.5	2	90.0
	2	74.8	70	19	
		75.2	94.5	5	90.0
	3	74.8	70	19	
		75.2	94.5	12	69.0
	4	74.8	70	19	
		75.2	94.5	21	45.0
11	1	55.1	64	19	
		55.6	90	2	106.0
	2	55.1	64	19	
		55.6	90	5	97.0
	3	55.1	64	19	
		55.6	90	12	88.0
	4	55.1	64	19	
		55.6	90	17	79.0
	5	55.1	64	19	
		55.6	90	21	72.0
12	1	64.7	70.5	19	
		65.8	90.5	2	97.6
	2	64.7	70.5	19	
		65.8	90.5	5	97.6
	3	64.7	70.5	19	
		65.8	90.5	12	74.0
	4	64.7	70.5	19	
		65.8	90.5	17	50.0
	5	64.7	70.5	19	
		65.8	90.5	21	43.0

first the improvement in uniformity more than offset the darkening in color in its effect upon the commercial value. Probably an initial increase in value would not have occurred in a crop cured at optimum relative humidity. As the darkening became more pronounced, the commercial value of the tobacco decreased. This was especially true at the higher relative humidities.

It became apparent as the test progressed that the tobacco subjected to 70 percent relative humidity was not deteriorating at a rate which would be practically important. Even the tobacco in 90 percent relative humidity chambers was not deteriorating as rapidly as it sometimes does in the barns, so after 19 days the chambers originally set at 70 percent relative humidity were raised to 95 percent. In table 10 the results are presented in a way which makes their practical value more apparent. The rate of deterioration after the initial improvement, if any, is expressed as the average number of days required for a decrease of 10 percent in value according to the graders' estimates. It will be seen that no deterioration was found at 70 percent humidity at any temperature tested. When the tests conducted at relative humidities between 70 and 81 percent are grouped, some deterioration is shown but the effect of temperature, if present, is obscured by experimental error. At humidities from 85-89 percent the rate of deterioration is quite marked and is somewhat influenced by temperature. At higher humidities the deterioration becomes even more rapid. Thus we may conclude that it is not good farm practice to allow cured tobacco hanging in the barn to be exposed to relative humidities above 70 percent for longer than is necessary to bring the tobacco into condition for stripping, unless it is badly mottled.

Table 10. Effect of temperature and relative humidity on the rate of deterioration of cured tobacco. Results expressed as number of days required for a 10 percent decrease in value.

Relative humidity	55° F	65° F	75° F
Percent	days	days	days
70	> 40	> 40	> 40
75 — 81	> 40	22	40
85 — 89	18	14	7
90 — 95	5	3	2

= more than.

It seems probable that the principle of limiting factors is operating in this case. As long as the relative humidity is so low that the moisture content of the tobacco is insufficient for the

chemical reactions to take place rapidly, moisture content and relative humidity is the limiting factor. At higher humidities the increased moisture content allows a much more rapid reaction and temperature becomes important in determining the rate. It is obvious, however, that the practical method of preventing loss from this source is to prevent the existence of high humidity in the barn for extended periods, even if this may require the use of heat. The times given for 10 percent loss in value are maximum rather than minimum figures because of the effect of the initial mottled condition of the tobacco and the influence upon the graders of the relatively high prices paid in 1939 for the darker grades of tobacco.

Moisture Content of Cured Tobacco. While some of the previously described experiments were being conducted, it was possible to investigate the effect of temperature and relative humidity upon the moisture content of cured tobacco. In order to do this satisfactorily, the samples had to be small enough for equilibrium to be reached in a reasonable time, but had to possess the physical structure of leaf tobacco and at the same time be sufficiently uniform for the different tests. Consequently the leaves were cut transversely into strips about 1 inch wide with the "stem" or midrib left in. Barn-cured tobacco similar to that described in the previous experiment was used. Leaf from the various stripping-room grades was mixed in the proportion in which it was present in the crop. Six-gram samples were weighed into duplicate moisture dishes for each condition. The dishes were weighed from time to time to determine when equilibrium had been reached. The results were determined both on the basis of the original moisture content of the tobacco and the change in weight while in the chamber, and on the basis of moisture determinations conducted at the end of the experiment. Identical results were obtained when equilibrium was approached from either direction. The results are presented in figure 5. Three different temperatures were used, 55°, 65°, and 75°F. There is no evidence from these results of any significant effect of temperature on moisture content of cured Burley tobacco. However, it is well known by all handlers of tobacco that it seems to be in poorer case when it is cold. This is probably due to the effect of temperature on the elasticity of the organic materials of the leaf since it does not appear to be due to the moisture content.

It can be seen from figure 5 that relative humidity has a very marked effect upon moisture content. This effect is much

is more marked at humidities above 70 percent than below. On theoretical grounds it seems quite likely that moisture may be present in some other physical state at high relative humidities in addition to that in which it is present at low humidities. The change of slope of this curve in the neighborhood of 70 percent relative humidity is much more marked than that given by other curves (2) for flue-cured or Porto Rican cigar leaf. It is important to note the relationship between this change of slope of the curve about 70 percent and the results of the preceding experiments.

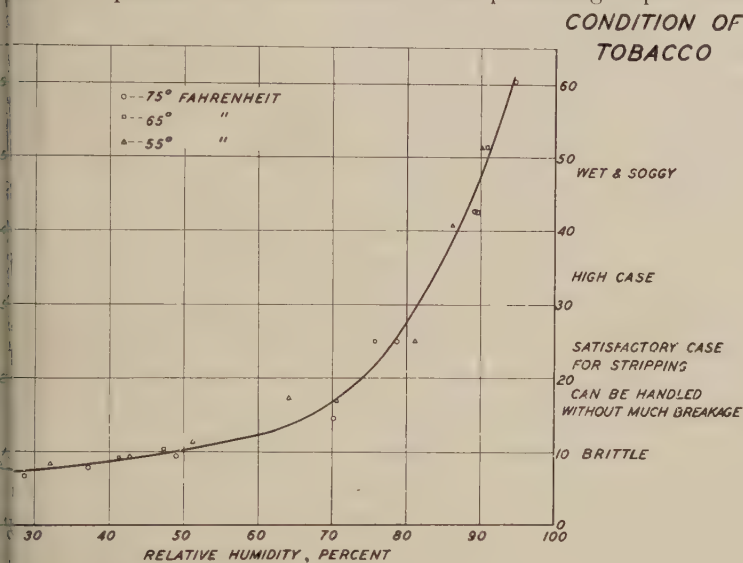


FIGURE 5. Effect of relative humidity on the moisture content of Burley tobacco.

The minimum relative humidity at which Burley tobacco darkens during curing, lies at 75-80 percent, a little above this point. The minimum relative humidity for curing Burley lies at 65-70 percent, a little below this point. The most critical stage for houseburning is to be just after the tissue turns from yellow to brown; that is, just after the cells have died and lost the degree of organization and impermeability associated with life, but before the moisture content has reached equilibrium with the surrounding air. In tobacco curing at optimum air conditions, the moisture content of the leaf at this critical time is undoubtedly above the 15 to 20 percent range in which it would be in equilibrium with air at 70 percent relative humidity, as shown in figure 5, but should fall below this range in

a short time and so lose the excess moisture which seems to be essential if the undesirable changes are to take place.

It is fortunate that the feel of cured tobacco and the optimum curing conditions are both related to relative humidity, because this makes possible the use of the feel of the cured leaves as a means of control in curing. This has been used more or less consciously by most growers for many years. It can be used more intelligently if the results presented in this bulletin are used in connection with the notations on the side of figure 5. At the optimum relative humidity for curing, the cured tobacco will be too dry to handle extensively without some breakage; that is, not "borderline dry" but nearer to that than to good case.

DISCUSSION

The results presented indicate that the relative humidity during curing is much more critical than temperature in its influence upon the quality of cured Burley tobacco. This had been suspected by some tobacco growers and men in the Agricultural Services working with them, but could not be proved without equipment in which it was possible to control the two variables independently. Most people are familiar with the concept of temperature and the use of a thermometer, but few are familiar with the concept of relative humidity or the use of any type of hygrometer. Heat has been used to alleviate the effects of unfavorable weather even in the curing of normal air-cured tobaccos for many years. However, most of those who use it do not realize that the beneficial effects obtained usually arise not directly from the increased temperature but from the effect of temperature upon the moisture-holding capacity of the air and consequently upon the relative humidity. This relationship can be shown to best advantage by means of a psychrometric chart such as is used by air conditioning engineers. A psychrometric chart covering the range of conditions which frequently exist in air-curing barns is given in figure 6. This type of chart differs from an ordinary graph in that each point on the chart represents a given temperature and moisture content of air. The temperature represented increases from left to right and the moisture content from bottom to top. This vertical scale is calibrated in terms of dew-point temperature or the temperature to which the air would have to be cooled for dew to form. The curved line at the left represents the conditions at which air is saturated with

moisture. The other curved lines roughly parallel to the saturation curve represent the percent of saturation of the air at the corresponding conditions, or the percent relative humidity. Similarly the diagonal straight lines represent wet-bulb temperature. Thus the condition most frequently used in the foregoing experiments, 75° and 68 percent relative humidity, is shown by the point enclosed with a circle, in figure 6. The corresponding wet-bulb temperature is seen to be 67.7°F and the dew-point temperature to be about 63°F. If the air of composition represented by this point is heated, without change in moisture content, the point representing its composition moves horizontally to the right. This results in a

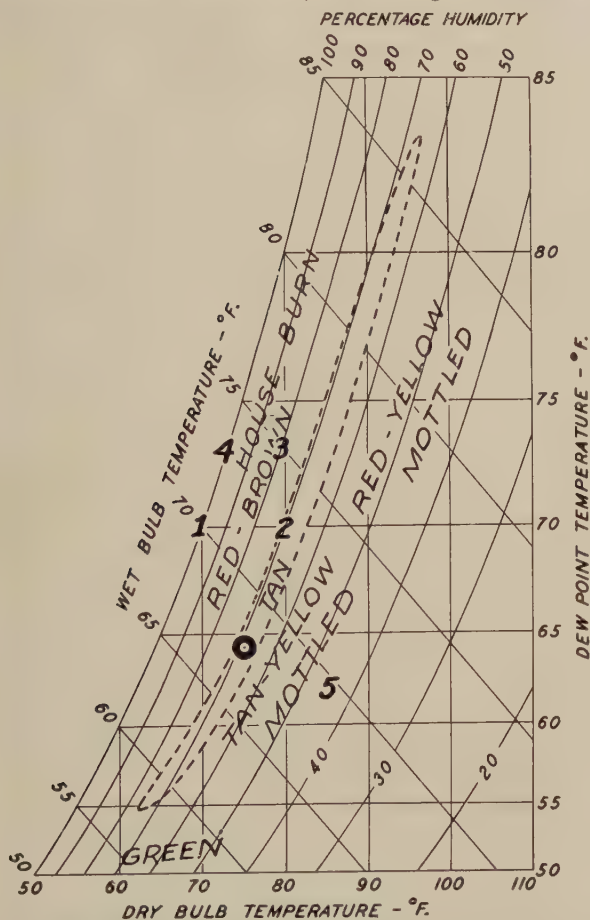


FIGURE 6. Psychrometric chart showing relationships between temperature, relative humidity, and quality of cured tobacco.

decrease in the relative humidity. If moisture is added to this without change in temperature, the point representing the composition would rise vertically. Similarly cooling, drying and combinations of changes can be represented on the chart.

The area representing satisfactory curing conditions as determined on the basis of the results is approximately that enclosed by the dotted line in figure 6. Here again it may be seen that the relative humidity is more critical than temperature. It can also be seen that absolute humidity or moisture content of the air does not bear any direct relation to the optimum conditions.

Let us consider the manner in which this chart may be used in reaching a clearer understanding of the conditions existing in a curing barn. Assume that the temperature in the barn is 70° and the air saturated, or at 100 percent relative humidity. This is represented on the chart by the point marked 1. The optimum zone may be reached by reducing the moisture content of the air or by heating the air. If it is a dry, sunny day outside, the former method is preferable; that is, the ventilators should be opened and the moist air let out. However, if the weather is rainy and the conditions outside are about the same as inside, the moisture will not move out of the tobacco. If the relative humidity inside the barn can be lowered, the moisture will evaporate from the leaves. The most practical method of lowering the humidity and circulating the air is by the use of fires. When the temperature has been raised about 10°F, the humidity will be reduced from 100 percent to 70 percent, a satisfactory value. This point is designated as 2 on the chart. However, this lower relative humidity will cause an increased rate of evaporation, bringing more moisture from the tobacco into the air, and will result in some such condition as the barn as that designated by 3. This point is outside the optimum zone, so more heat is required to dry this more moist air until it reaches the optimum zone again. If the barn is closed tight it is obvious that a satisfactory state will not be reached. However, the moisture content at point 3 is greater than at point 1, so it is not possible to eliminate moisture by ventilation even though it may be raining outside the barn. In many cases the cracks in the barns are large enough so that satisfactory curing may be done even when an attempt is made to close the barn and keep the heat in, on the false assumption that the higher temperature is directly beneficial. In other cases where the barn is tight enough to hold the high hu-

ity under conditions where this is desirable, much damage is done thru the use of fires without ventilation, especially if the tobacco is crowded. This damage occurs most frequently in the sheds, where the air which has picked up a large amount of water, at point 3 in figure 6, comes in contact with the cold walls, and is cooled. This air may reach a composition such as represented by point 4, which will cause the condensation of moisture on the tobacco and will result in extensive houseburn in the sheds, perhaps more severe than would have occurred if no fires had been used. This situation can be prevented by the use of more ventilation combined with a more uniform distribution of heat in the shed. This latter may be accomplished by moving some of the fires out into the sheds.

Another cause of injury to Burley tobacco thru the use of heat arises from the fact that many growers use fires whether they are necessary or not. If the condition of the air in the barn is represented by some such point as 5 in figure 6 (relative humidity about 45 percent) a condition common during the dry curing season of 1939, the use of heat, driving the condition further to the right on the chart, will injure rather than improve the tobacco. It is obvious from the chart that the moisture content of the air should be increased under these circumstances to provide optimum conditions for curing. This can be done by closing the ventilators. It should be pointed out that this optimum zone applies to the daily average, and not to the day readings which are most likely to be observed. It also concerns conditions up among the tobacco and just near the driveway or outside walls, where satisfactory tobacco is usually obtained even if care is not used. Reducing relative humidity by the use of heat is possible because of the relationship between temperature and moisture-holding capacity of air, and consequently between temperature and relative humidity. It is practical in curing Burley tobacco because of the wide optimum temperature range, making it possible to hold the temperature at the value necessary for humidity control without serious danger of exceeding the limits of favorable temperature.

In figure 6 an attempt has been made to indicate the colors which can be expected to appear in lug leaves of tobacco cured under the different air conditions, judging by the chamber experiments. If the curing conditions are optimum, a tan or light brown leaf is obtained. If the relative humidity is higher, a red-

brown is obtained and at still higher humidities the dark brown or nearly black of houseburn appears. As the humidity is reduced below the optimum, mottled colors are obtained with the red-yellow mixture predominant at high temperature and green at low temperatures. This gives some indication not only of the optimum conditions for Burley tobacco, but also of reasons for its difference from other types. Experiments conducted as another part of the general study indicate that dark-fired tobacco has an optimum relative humidity during curing in the neighborhood of 80 percent. The results obtained for Connecticut cigar leaf previously referred to give a similar optimum. In both these types the trade preference is for darker color, more like that which is produced by Burley at these higher humidities. On the other hand, the yellow colors preferred in flue-cured tobacco may be expected to be produced at a low humidity such as must exist in a flue-curing barn at the time when the color is set.

The question may be raised as to why relative humidity during curing is more critical in determining the quality of cured tobacco than temperature. It can be shown by results obtained in this work such as those presented in figures 1 and 2, that the rate of loss of weight increases with increasing temperature if the relative humidity is held constant. If the effect of temperature upon the rate of weight loss during the early part of the curing period is averaged from all available data, the results indicate that the effect is equal or slightly greater than the effect of temperature upon the rate of many chemical reactions, which approximately double in rate for each 10°C (18°F) rise in temperature. We may assume that optimum quality is related to a definite chemical composition. The composition of the cured product depends upon the stage which has been reached when the leaf dries and chemical changes are practically stopped. If the effect of temperature upon the rate of the chemical changes (curing) and upon the weight loss (chiefly drying) is about the same we may expect that the composition of the cured product will be similar at different temperatures provided the relative humidity is constant, tho the time required may be much different. Relative humidity, on the other hand, has a very considerable effect upon the rate of drying but no direct effect upon the rate of chemical reactions. Consequently we may expect the chemical changes to go much farther at high than at low relative humidity before they are stopped by drying. This same reasoning seems

py to the different types of tobacco much as it does in respect
ne colors of the cured product. Flue-cured tobacco is known
possess a higher sugar content than other types, presumably
use the leaf is dried before the sugar is used in respiration.
ey is low in sugar and starch but it is probable from other work
progress that the nitrogen compounds are not broken down as
pletely as are those of cigar tobacco. Thus Burley appears to
py an intermediate position in this respect, related to the inter-
iate relative humidities most favorable for its curing.

PLANS FOR FUTURE WORK

Work is to be continued to determine whether the optima are
ited by seasonal growing conditions, maturity of the tobacco,
ot or disease injury, and soil type. Additional work will be
o: to check more closely upon the effect of diurnal fluctuation
to investigate further the possibility of different optimum con-
ns at different stages of the cure. It is hoped that work can
started soon on possible changes in the design of barns to make
optimum conditions here described more readily obtainable.
ever, these results can be applied to a considerable degree in
barns even as at present built and heated if care and thought
eased by the operator.

SUMMARY

This bulletin describes experiments conducted in air-con-
rned chambers being used as a part of an extensive study of
tobacco curing being conducted at this Station and discusses the
ical value of the results obtained to date.

Good quality Burley tobacco can be cured at temperatures
0, 60°F to at least 90°F provided the relative humidity is near
imum.

The optimum constant relative humidity for curing Burley is
t 65 to 70 percent. There is no evidence so far that the optimum
fferent at different times during the season or for tobacco of
rent degrees of maturity. There is some indication that the
imum relative humidity is slightly higher at lower temperatures
at high, but this requires additional investigation.

Burley tobacco cured at too high a relative humidity is darker
if cured at optimum conditions. Burley tobacco cured at too
a relative humidity tends to be mottled, with yellow areas pre-
nant at medium temperatures, red areas predominant at high

temperatures, and a green cast or green spots, especially at low temperatures.

A relative humidity of 77 percent is undesirable when held for as long as a week, but this does not preclude the possibility that a humidity somewhat above that found to be the optimum constant value (65-70 percent) may be advisable for a shorter time at the beginning of the curing period.

No evidence of difference in quality has been obtained so far resulting from a diurnal fluctuation such as is normally obtained in the barn, as compared with constant conditions the same as the average of the fluctuating conditions. Thus the conditions in the barn may be allowed to fluctuate between day and night provided the average conditions are near the optimum. This decreases the expense of control.

Split tobacco loses weight during curing at a more rapid rate than tobacco which has not been split. Consistent differences in quality between split and tied tobacco were not obtained.

There is no direct connection between the rate of weight loss and the quality of the resulting tobacco.

Cured tobacco should not be exposed to a relative humidity above 75 percent for longer than necessary to bring the tobacco into case for stripping, or damage is likely to occur. The rate of damage increases rapidly as the relative humidity rises.

The moisture content of cured Burley tobacco rises slowly as the relative humidity is increased up to about 70 percent. From this point on toward higher humidities, the moisture content rises at an increasing rate. This critical value, at which the extent of moisture uptake increases, and possibly an additional type of moisture absorption appears, is probably related to the optimum relative humidity for curing and the maximum safe relative humidity after curing.

Temperature does not appear to have any significant effect upon the moisture content of the tobacco so long as the relative humidity remains constant. There is some decrease in pliability of tobacco at low temperatures, but most of the difference in feel of tobacco results from change in relative humidity rather than directly from change in temperature.

The feel of cured tobacco can be used satisfactorily in applying the results here presented if one becomes accustomed to the relationship of this property to relative humidity.

The use of heat in a tobacco-curing barn as a means of reducing the relative humidity is practical because of the relationship between temperature and relative humidity and because of the wide optimum temperature range as compared with the narrow optimum humidity range.

LITERATURE CITED

- Anderson, P. J., Swanback, T. R., and Street, O. E. Tobacco Substation at Windsor. Report for 1931. Conn. Agr. Sta. Bull. 335: 268-274. 1932.
- Carrier Engineering Corporation. Drying and processing of materials by means of conditioned air. Newark, N. J. p. 181.
- Cooper, A. H., Delamar, C. D., and Smith, H. B. Drying and curing bright leaf tobacco with conditioned air. Ind. Eng. Chem. 32: 194-198. 1940.
- Garner, W. W. Principles and practical methods of curing tobaccos. U.S.D.A. Bureau of Plant Industry, Bull. 143: 1-54. 1909.
- Johnson, James. Constant temperature and humidity chambers. Phyto-path. 18: 227-238. 1928.
- and Ogden, W. B. The relation of air conditions to tobacco curing. Wis. Agr. Expt. Sta. Res. Bull. 110: 1-48. 1931.
- Bannon, L. S. A laboratory for use in determining the influence of various temperatures and relative humidities on the final quality of air-cured tobacco. Heating, Piping and Air Conditioning 11: 699-702. 1939.
- Street, O. E. Curing experiments. Conn. Agr. Expt. Sta. Bull. 326: 411-418. 1931.
- Swanback, T. R., Street, O. E., and Anderson, P. J. Tobacco Substation at Windsor. Report for 1932. Conn. Agr. Expt. Sta. Bull. 350: 499-507. 1933.

Kentucky
Agricultural Experiment Station

University of Kentucky

DISTILLERY SLOP FOR HOGS

BULLETIN NO. 408



Lexington, Ky.

August, 1940

(385)

CONCLUSIONS

1. Very slow gains result if distillery slop is fed alone.
2. Soft and even oily carcasses are produced if distillery slop is fed alone.
3. Distillery slop should be supplemented with a good starchy feed, such as corn, in the proportion of not less than one bushel of corn to 50 gallons of slop. A lower ratio produces unsatisfactory carcasses.
4. Faster and more economical gains are made if tankage as well as corn is fed with the slop. Furthermore, if slop is not properly supplemented, the gains are very slow and soft carcasses are produced.
5. Thin distillery slop should be settled several hours and only the thicker portion fed after the supernatant liquid has been dipped off.
6. In feeding distillery slop to hogs it was found that under the most favorable conditions, with corn valued at 60 cents per bushel and tankage at \$65 a ton, thin slop is worth about 1/2 cent per gallon, settled slop about 3/4 cent per gallon and whole slop about 1 cent per gallon, if fed with corn and tankage in the proportions recommended. These values do not take into consideration the cost of haulage which would vary considerably according to mileage traveled and equipment used.

BULLETIN NO. 408

Distillery Slop for Hogs

By E. J. WILFORD

Distillery slop is the material which remains after the distillation of fermented mash, in making whisky or alcohol from grain. Most of the starch has been taken out in the processes of mashing, fermenting and distilling but most of the protein, fat and fiber of the original grain are in the slop; hence the material is relatively rich in protein and fat. The kind of grain used affects its composition; if the mash was made mainly from corn, the proportions of protein and fat are larger and that of fiber is smaller than if rye predominated but in any case the feeding value of the grain residue in the slop is considerable. To save some of this value, the common practice of distillers is to strain out as much of the undissolved matter as practical. This recovered material is dried and sold as distillers' dried grains. How to dispose of the large volume of thin liquid which passes thru the strainers is a difficult problem for distillers. Because of the unbalanced character of its feed constituents and the large proportion of water it is unsuitable, alone, as a feed for hogs. Besides, it was found that carcasses of hogs fed distillery slop were so soft as to be unsatisfactory to the packers. The experiments reported in this bulletin were made at the request of farmers, to try to find a way to use distillery slop economically, in feeding hogs, without producing soft pork. The slop was obtained from a local distillery which was using corn as the principal grain.

Kinds of Slop Fed. Three kinds were obtained at the distillery: whole slop, thin slop and evaporated slop. Whole, or straight, slop, sometimes called thick slop, is the material just

as it is drawn from the still. Thin slop is the part which passes thru the strainers, in the process of making dried grains. It is a thin, whitish liquid. Evaporated slop is a sirupy material of the consistence of semisolid buttermilk, made from thin slop by evaporating a large part of the water. A fourth kind was prepared on the farm, by letting thin slop settle for a few hours and removing the nearly clear top part, thus reducing the volume about a third. Samples of the slop to be fed were taken for analysis at intervals of a week or more, during the experiments. Table 1 contains averages of these analyses.* Computed from the percentages of total solids, 3 gallons of thin slop, or $2\frac{1}{2}$ of settled slop, or $1\frac{1}{2}$ of whole slop, or about 3 quarts of evaporated slop would be required to supply a pound of dry food material.

The composition of the water-free solid matter, calculated from these analyses, is given in table 2. It is noteworthy that the evaporated slop contains a distinctly larger percentage of fat than the thin slop.

PRELIMINARY TEST

To get information for further experimentation, three lots of 10 pigs each were fed distillery slop during 15 weeks, as

Table 1. Average analyses of the distillery slop fed in the experiments. Percent.

Kind of slop	Thin	Settled	Whole	Evaporated
Protein	1.1	1.5	2.3	4.3
Fat	0.4	0.6	0.6	2.8
Fiber	0.2	0.3	0.7	0.7
Nitrogen-free extract	1.8	2.0	4.0	7.6
Ash	0.3	0.3	0.3	1.0
Total solids	3.8	4.7	7.9	16.4
Water	96.2	95.3	92.1	83.6
Number of analyses averaged....	5	11	3	3

* The analyses were made by Dr. G. Davis Buckner and Miss Amanda Harms.

Table 2. Composition of the total solids in the slop, calculated water-free. Percent.

Kind of slop	Thin	Settled	Whole	Evapo- rated
Protein	29.0	32.8	28.5	26.2
Starch	10.5	13.2	8.0	17.1
Fiber	5.2	5.4	9.2	4.3
Nitrogen-free extract	47.4	42.8	50.5	46.3
Ash	7.9	5.8	3.8	6.1
	100.0	100.0	100.0	100.0

shown in table 3. The pigs had been double treated for cholera and round worms and the males had been castrated. The three lots were made as nearly equal as possible, as to weight, sex, breed and litter. They were kept in pens 35 by 112 feet, practically free of forage, or "dry lots", in each of which was a movable house, 8 by 10 feet. Another house was added when the pigs had grown larger. The slop was fed in 6-foot galvanized iron troughs and the shelled corn and tankage, separately, in single-type self feeders, all on wooden platforms.

The hogs in lot 1 did not drink much slop at first, but by the end of five weeks the average daily consumption per hog was about 35 pounds, or four gallons. They lost weight three weeks out of the five and made a net loss of 58 pounds in 35 days, or an average daily loss per hog of about $1\frac{1}{6}$ pound. This loss probably was due to the high percent of water, for this kind of slop contains less than 4 pounds of solids in every hundred pounds, or about $\frac{1}{3}$ pound in one gallon. The solids are not whole cereal grains but are grain residues from which almost all the starch has been extracted. Thus the hogs had to consume a large amount of slop in order to even maintain their weight; and the ingestion of so much water caused the kidneys to be overworked.

Because of the bad results with thin slop alone, the hogs in lot 1 were fed settled slop, corn and tankage during the next 10 weeks. In addition to all the settled slop they would eat, they were fed shelled corn at the rate of 50 pounds to each 50

as it is drawn from the still. Thin slop is the part which passes thru the strainers, in the process of making dried grains. It is a thin, whitish liquid. Evaporated slop is a sirupy material of the consistence of semisolid buttermilk, made from thin slop by evaporating a large part of the water. A fourth kind was prepared on the farm, by letting thin slop settle for a few hours and removing the nearly clear top part, thus reducing the volume about a third. Samples of the slop to be fed were taken for analysis at intervals of a week or more, during the experiments. Table 1 contains averages of these analyses.* Computed from the percentages of total solids, 3 gallons of thin slop, or $2\frac{1}{2}$ of settled slop, or $1\frac{1}{2}$ of whole slop, or about 3 quarts of evaporated slop would be required to supply a pound of dry food material.

The composition of the water-free solid matter, calculated from these analyses, is given in table 2. It is noteworthy that the evaporated slop contains a distinctly larger percentage of fat than the thin slop.

PRELIMINARY TEST

To get information for further experimentation, three lots of 10 pigs each were fed distillery slop during 15 weeks, as

Table 1. Average analyses of the distillery slop fed in the experiments. Percent.

Kind of slop	Thin	Settled	Whole	Evapo- rated
Protein	1.1	1.5	2.3	4.3
Fat	0.4	0.6	0.6	2.8
Fiber	0.2	0.3	0.7	0.7
Nitrogen-free extract	1.8	2.0	4.0	7.6
Ash	0.3	0.3	0.3	1.0
Total solids	3.8	4.7	7.9	16.4
Water	96.2	95.3	92.1	83.6
Number of analyses averaged....	5	11	3	3

* The analyses were made by Dr. G. Davis Buckner and Miss Amand Harms.

Table 2. Composition of the total solids in the slop, calculated water-free. Percent.

Kind of slop	Thin	Settled	Whole	Evapo- rated
Protein	29.0	32.8	28.5	26.2
Starch	10.5	13.2	8.0	17.1
Fiber	5.2	5.4	9.2	4.3
Nitrogen-free extract	47.4	42.8	50.5	46.2
Moisture	7.9	5.8	3.8	6.1
	100.0	100.0	100.0	100.0

shown in table 3. The pigs had been double treated for cholera and round worms and the males had been castrated. The three lots were made as nearly equal as possible, as to weight, sex, breed and litter. They were kept in pens 35 by 112 feet, practically free of forage, or "dry lots", in each of which was a movable house, 8 by 10 feet. Another house was added when the pigs had grown larger. The slop was fed in 6-foot galvanized iron troughs and the shelled corn and tankage, separately, in single-type self feeders, all on wooden platforms.

The hogs in lot 1 did not drink much slop at first, but by the end of five weeks the average daily consumption per hog was about 35 pounds, or four gallons. They lost weight three weeks out of the five and made a net loss of 58 pounds in 35 days, or an average daily loss per hog of about $1\frac{1}{6}$ pound. This loss probably was due to the high percent of water, for this kind of slop contains less than 4 pounds of solids in every hundred pounds, or about $\frac{1}{3}$ pound in one gallon. The solids are not whole cereal grains but are grain residues from which almost all the starch has been extracted. Thus the hogs had to consume a large amount of slop in order to even maintain their weight; and the ingestion of so much water caused the kidneys to be overworked.

Because of the bad results with thin slop alone, the hogs in lot 1 were fed settled slop, corn and tankage during the next 10 weeks. In addition to all the settled slop they would eat, they were fed shelled corn at the rate of 50 pounds to each 50

Table 3. Preliminary test of feeding distillery slop to hogs, in 3 periods of 35 days each. Ten hogs in each lot. Weights are averages per hog, in pounds.

Period and items observed	Lot 1	Lot 2	Lot 3
First five weeks	Thin slop	Settled slop	Settled slop, corn
Initial weight	102.8	102.8	101.0
Total gain (+) or loss (—)....	—5.8	—1.3	+15.0
Daily gain (+) or loss (—)....	—0.17	—0.04	+0.43
Slop consumed	836.7	765.5	593.4
Corn consumed .....	.....	.....	69.0
Second five weeks	Settled slop, corn and tankage	As before	As before
Initial weight	97.0	101.5	116.0
Gain	49.0	14.5	21.6
Daily gain	1.40	0.41	0.62
Slop consumed	704.	1258.	704.
Corn consumed	112.	.....	112.
Tankage consumed	11.2	.....	.....
Third five weeks	Same as period 2	As before	Tankage added
Initial weight	146.0	116.0	137.6
Gain	42.5	17.0	50.7
Daily gain	1.21	0.49	1.45
Slop consumed	820.0	1602.5	820.0
Corn consumed	132.5	.....	132.5
Tankage consumed	13.25	.....	13.25

gallons of thin slop used in preparing the settled slop. Tankage was fed at the rate of 1/10 the weight of the corn. Near the end of the next five-week period these 10 hogs were consuming daily 200 pounds of settled slop, 35 pounds of shelled corn and 3.5 pounds of tankage. The first week after the change, the 10 hogs gained 160 pounds. The total gain for this five weeks was 490 pounds, or an average daily gain of 1.40 pounds per hog. The gains during this period were remarkable because these same hogs, during the previous five-week period, lost 58 pounds on thin slop alone. They were continued on the same feeds for another five weeks in which time they gained 425 pounds, or an average daily gain of 1.21 pounds.

The 10 hogs of lot 2 were fed all the settled slop they could eat thruout the 15 weeks. They lost 13 pounds in the first five weeks, gained 145 pounds in the second and 170 pounds in the third. The average daily gain per hog during the 15 weeks was only .29 pound, a small gain, much less than that of the hogs in lot 1 which also had corn and tankage.

The 10 hogs in lot 3 were fed all the settled slop they would eat and 50 pounds of shelled corn to each 50 gallons of thin slop used in preparing the settled slop. The gain was 150 pounds in the first 5 weeks and 216 pounds in the second, or a total gain of 366 pounds in 10 weeks. The average daily gain per hog was .52 pound, or almost twice as much as in lot 2 which did not have corn. Toward the end of the second 5-week period, the hogs in lot 3 seemed to lose their appetite; therefore tankage was added to correct the loss of appetite. The ratio of corn to slop was kept the same and the amount of tankage fed was one-fifth the weight of the corn. The first week after this change was made the 10 hogs regained their appetite and gained 94 pounds which was 73 pounds more than the week before and 20 pounds more than in any previous week. Their total gain in this five-week period was 507 pounds, or an average daily gain of 1.45 pounds per hog.

This test showed that settling thin slop and feeding only the thicker portion was beneficial; that addition of corn to settled slop produced larger and more economical gains, and that addition of tankage to the corn and settled slop increased the gains still more. The grain residues in settled slop have lost most of the starch during fermentation, and the addition of corn supplies the carbohydrate necessary to increase the gain. The tankage, an animal product, not only adds to the proteins of the grain residues but also increases the palatability and efficiency of the proteins; therefore it is good practice to feed corn and tankage with the settled slop.

Quality of the Meat. Most of the hogs in this test were slaughtered in the Station abattoir and after a 48-hour cooling at an average temperature of 34° F., their carcasses were compared with those from hogs that had been fed only corn and

tankage. The carcasses from the slop-fed hogs were soft as compared with the check carcasses. The carcasses from lot 2 (settled slop alone thruout the 15-week period) were very soft and even oily. Those from lot 1 (corn and tankage the last 10 weeks) averaged a trifle harder. Those from lot 3 (corn thruout the test and tankage the last 5 weeks) averaged harder than those from lot 1. These differences were so marked that students in the Meats Course who had no training in judging softness of carcasses, detected the differences rather accurately.

The sausage made from these soft carcasses was leathery in texture and lacked the desirable flavor of good sausage. The loin appeared glossy, especially in the softer carcasses. The lard rendered from the cutting fats was soft and did not harden even when kept in cold storage at a temperature averaging 34° F. Bacon from these soft carcasses remained soft and pliable after complete curing and smoking, even after having been kept in cold storage for a week or more. Notwithstanding these unfavorable conditions, there were no serious losses in the bacon cuts. But trouble developed in the hams which were cured in the usual way. A larger percentage than usual spoiled or were decidedly off flavor. The spoilage started near the bone, and the area varied in size. In some hams the area of spoilage spread rather rapidly and in others the spread was slow.

How the Meat was Cured. The curing mixture for the hams was made of 7½ pounds of salt, 2½ pounds of sugar and 2 ounces of saltpeter for each 100 pounds of meat. One-third of the mixture was sprinkled on the hams immediately after the carcasses were cut up; three days later a second third was rubbed on and three days after this the last portion was rubbed on. The meat stayed in cure twenty-one days, in the cooler, at about 37° F. After the curing time, the hams were brushed off with a stiff brush and soaked in lukewarm water for about an hour. They were taken out and dried thoroly before starting the smoke. After the smoke was begun, the smoking was fairly steady for about five or six days, or until the hams became an amber color. An attempt was made not to get the room too hot or, as the packers call it, the hams were "cold smoked".

The bacon was treated with a mixture of 3 pounds of salt, 1½ pounds of granulated sugar and 5 ounces of saltpeter to 100 pounds of

meat. Each piece was thoroly rubbed with this mixture, packed in a box in which it fitted tight and put under pressure. It remained in this cure at the same temperature as the hams for twenty-one days. At this time it was removed from the cure, dipped in lukewarm water and hung up to dry before smoking. It went thru the same form of smoking as the hams but usually came out of the smokehouse a day or so before the hams, as it seemed to take the smoke more readily.

THE SECOND TEST

This was planned to get a comparison of the feeding values of the different forms of slop and determine the effect of the slop and supplements upon the hardness of pork produced. It began with five lots of nine hogs each, averaging in weight 143 pounds. Since hogs were taken out at the end of the 5th and 6th weeks for testing the quality of the meat, the following plan was used in computing data:

$$\begin{array}{rcl} 9 \times 35 \text{ days} & = & 315 \text{ hog days} \\ 8 \times 7 \text{ days} & = & 56 \text{ hog days} \\ 7 \times 7 \text{ days} & = & 49 \text{ hog days} \end{array}$$

$$49 \text{ days} \quad 420 \text{ hog days}$$

420 hog days were used in computing data for lots 1, 2, 3 and 4. One hog in lot 5 died at the beginning of the experiment, leaving only 8 hogs. Data for that lot were computed as follows:

$$\begin{array}{rcl} 8 \times 35 \text{ days} & = & 280 \text{ hog days} \\ 7 \times 7 \text{ days} & = & 49 \text{ hog days} \\ 6 \times 7 \text{ days} & = & 42 \text{ hog days} \end{array}$$

$$49 \text{ days} \quad 371 \text{ hog days}$$

371 hog days were used in computing data for lot 5.

Lot 1 had corn and tankage, self fed, as a check. These hogs made an average daily gain of 1.8 pounds and required 172 pounds of corn and 42 pounds of tankage for each 100 pounds of gain.

Lot 2 had whole slop, all they would eat, with corn and tankage self fed. The average daily gain was a little over 2 pounds and required 310 pounds of corn, 30 pounds of tankage and 738 pounds (86 gallons) of slop; hence 86 gallons of slop saved 62 pounds of corn and 12 pounds of tankage.

Lot 3 had settled slop, all they would eat, with corn and tankage self fed. These hogs made an average daily gain of 1.9 pounds and required 322 pounds of corn, 34 pounds of tankage and 836 pounds (97 gallons) of settled slop for each 100 pounds of gain; hence 97 gallons of slop saved 50 pounds of corn and 8 pounds of tankage.

Lot 4 had evaporated slop, all they would eat, with corn and tankage self fed. These hogs made an average daily gain of a little over 2 pounds, and required 263 pounds of corn, 13 pounds of tankage and 757 pounds (88 gallons) of slop for each 100 pounds of gain; hence 88 gallons of evaporated slop saved 109 pounds of corn and 29 pounds of tankage.

Lot 5 had only evaporated slop, all they would eat. The average daily gain was 1.7 pounds. They required 2114 pounds (246 gallons) of slop for each 100 pounds of gain; hence 246 gallons of slop saved 372 pounds of corn and 42 pounds of tankage.

Table 4. Comparison of three forms of distillery slop in feeding hogs. Second experiment. Forty-nine days. Weights in pounds.

Items	Lots 1 to 4. Corn and tankage, self fed, and				Lot 5. Only evaporated slop, all they would eat
	1. Nothing else	2. Whole slop, all they would eat	3. Settled slop, all they would eat	4. Evaporated slop, all they would eat	
Initial weight per hog.....	142	146	143	145	141
Total gain per hog	84.3	95.6	88.6	97.2	69.6
Daily gain per hog	1.81	2.05	1.89	2.08	1.69
Corn consumed per hog	313.6	295.9	284.9	255.8	-----
Tankage consumed per hog	35.5	29.1	29.8	12.8	-----
Slop consumed per hog	-----	705.5	740.0	735.5	1470.4
Feed consumed per 100 lbs. gain	-----	-----	-----	-----	-----
Corn	371.9	309.7	321.8	263.1	-----
Tankage	42.1	30.4	33.6	13.1	-----
Slop	-----	738.4	835.6	756.6	2114.1
Number of hogs sent to a Government-inspected plant	2	4	2	3	5
Grades at the plant	2 hard.	3 med. hard. 1 soft.	1 hard. 1 med. soft.	1 hard. 1 med. soft. 1 soft.	2 soft. 3 oily.

Value of Slop. The money value of the slop, under the conditions of this experiment, may be estimated by assuming that the amount of slop required to produce 100 pounds gain is worth as much as the corn and tankage saved by feeding this quantity of slop. If tankage is worth \$65. a ton and shelled corn 60 cents a bushel (56 lbs.), whole slop would be worth about 1.2 cents, settled slop about 0.8 cents and evaporated slop about 2.4 cents a gallon, when fed with corn and tankage, or 2.2 cents when fed alone. Assuming that one-third of the main slop is wasted in preparing settled slop, thin slop would be worth about 0.6 cents a gallon. These estimates do not take into consideration the quality of pork produced. The range of dockage for soft to oily hogs was from \$1.50 to \$2.50 per hundred live weight at most of the yards and some packers refused to buy the oily hogs fed distillery slop at any price.

Quality of the Meat. The gradings at the packing house

Table 5. Quality of hogs from the second test, slaughtered at the University abattoir, one from each lot, after 5 and 6 weeks, respectively.

Lot and feeds	No. days on feed	Ave. daily gain, lbs.	Weight lost in 24 hrs. fast percent	Weight lost by the carcasses in 48 hrs. at 34° F. percent	Dressing percent shipper style	Carcass grade
Lot 1. Corn and tankage						
1st sampling	35	2.06	3.2	2.0	79.5	h
2nd sampling	42	2.14	3.2	1.7	76.1	h
Lot 2. Whole slop, corn and tankage						
1st sampling	35	2.34	6.3	1.4	75.9	mh
2nd sampling	42	2.26	3.5	1.5	73.1	mh
Lot 3. Settled slop, corn and tankage						
1st sampling	35	1.88	4.9	1.1	78.7	ms
2nd sampling	42	1.78	3.2	2.0	78.9	s
Lot 4. Evaporated slop, corn and tankage						
1st sampling	35	2.17	5.3	2.2	77.2	ms
2nd sampling	42	2.67	2.9	1.9	77.0	mh
Lot 5. Evaporated slop						
1st sampling	35	2.06	9.1	1.7	73.5	o
2nd sampling	42	2.12	7.2	1.0	74.6	o

where these hogs were slaughtered were fairly uniform tho made by three observers independently. Carcasses of the hogs fed any form of slop tended to be softer than those of hogs

Table 6. Quality of the carcasses in experiment 2 as judged by three officials at a Government-inspected packing plant in Louisville. All hogs had as much slop as they would eat. Shrink includes the trip to Louisville by a truck.

Lot and feeds	Hog number	Breed ^a	Sex	Average daily gain	Shrink before butchering ^b	Dressed carcass ^c	Grade by three judges ^d		
							M	S	I
Lot. 1. Corn and tankage	30	DJ	M	Pounds 1.99	Percent 3.3	Percent 71.9	h	h	h
	39	PC	F	2.18	6.7	73.2	h	h	h
Mean	-----	-----	---	2.09	5.0	72.6	---	---	---
Lot 2. Whole slop, corn and tankage	92	DJ	M	1.63	2.1	71.1	h	h	h
	93	DJ	M	2.10	6.7	70.5	h	h	h
	94	DJ	M	1.65	3.8	66.0	s	s	s
	A3918	PC	F	2.61	2.8	71.4	h	h	h
Mean	-----	-----	---	2.00	3.9	69.8	---	---	---
Lot 3. Settled slop, corn and tankage	40	DJ	M	2.04	3.6	69.4	h	h	h
	A3917	PC	M	1.73	5.8	70.6	ms	ms	ms
Mean	-----	-----	---	1.89	4.7	70.0	---	---	---
Lot 4. Evaporated slop, corn and tankage	36	DJ	M	1.84	5.6	69.8	ms	ms	ms
	A3916	SPC	F	1.73	4.2	68.7	s	s	s
	A3915	PC	F	2.28	5.2	69.1	h	h	h
Mean	-----	-----	---	1.95	5.0	69.2	---	---	---
Lot 5. Evaporated slop only	37	DJ	M	1.49	5.6	68.6	s	ms	s
	38	DJ	M	1.67	3.4	66.0	s	s	s
	A3914	PC	F	1.63	7.3	68.4	o	o	o
	A3913	H	F	1.47	7.3	66.8	o	o	o
	A3912	H	M	1.53	10.3	65.9	s	o	s
Mean	-----	-----	---	1.56	6.8	67.1	---	---	---

^a DJ = Duroc Jersey; PC = Poland China; H = Hampshire; SPC = Spotted Poland China.

^b Difference between weight at the end of the feeding period and weight at the packing plant.

^c Warm weight, head off, hams faced, leaf out. Percent of the live weight in Louisville.

^d M = General manager; S = Superintendent of the Pork Division; I = Government Inspector; h = hard; ms = medium soft; s = soft; o = oily.

fed corn and tankage only. This was very evident where the hogs were fed evaporated slop alone; these carcasses were very soft and received the usual dockage given by this plant for oily pork. At the end of the 5th week a hog was taken from each lot, to be butchered at the Station abattoir, and at the end of the 6th week this procedure was repeated. The results are given in table 5.

The shrink during the fasting of the hogs before slaughtering was much greater in lot 5, which was fed evaporated slop alone, than in any other lot. The average shrink during a 24-hour period was about 20 pounds as compared with 6 or 7 pounds in the corn and tankage lot and, as at the packing house, it was very evident that all hogs fed slop produced much softer pork than those fed corn and tankage only. The difference was so marked that inexperienced men were able to detect it. In fact, the carcasses of hogs from lot 5 (evaporated slop alone) were much softer than the carcasses of hogs from any other lot.

From these figures it appears that the shrink of hams from hogs fed distillery slop was slightly more than that of hams

Table 7. Shrink of hams and bacon in curing and smoking. Hogs from the second experiment, slaughtered at the Experiment Station.

Lot and feeds		Number of pieces	Initial weight	Shrink in curing	Shrink in smoking	Total shrink
Lot 1. Corn and tankage	Hams	10	lbs. 140.3	percent 4.1	percent 6.9	percent 11.0
	Bacon	2	17.1	0.7	9.5	10.2
Lot 2. Whole slop, corn and tankage	Hams	6	95.5	3.9	7.4	11.3
	Bacon	1	9.0	1.4	13.9	15.3
Lot 3. Settled slop, corn and tankage	Hams	6	88.6	4.2	8.9	13.1
	Bacon	3	26.5	0.6	15.4	16.0
Lot 4. Evaporated slop, corn and tankage	Hams	6	94.8	4.4	7.6	12.0
	Bacon	2	17.8	2.4	14.5	16.9
Lot 5. Evaporated slop only	Hams	6	94.3	5.6	6.3	11.9
	Bacon	1	9.6	1.3	13.0	14.3

from hogs fed only corn and tankage. The shrink of bacon was considerably more for the slop-fed hogs than for those fed only corn and tankage.

THE THIRD TEST

This test was planned to see how small an amount of corn fed with settled slop, supplemented with tankage, would give satisfactory carcasses. Five lots of 10 hogs each were used. Lot 1, or check lot, had only corn and tankage, self-fed. The other four lots were fed all the settled distillery slop they would eat, with tankage in self feeders and a quantity of shelled corn ranging from two bushels in lot 2 to $\frac{3}{4}$ bushel in lot 5, to each 50 gallons of settled slop. After 52 days, 5 hogs from each lot were sent to a Government-inspected plant for slaughter. The remaining five continued in the test for 39 days. Accordingly, the following plan was used in computation.

$$\begin{aligned} 10 \times 52 \text{ days} &= 520 \text{ hog days} \\ 5 \times 39 \text{ days} &= 195 \text{ hog days} \end{aligned}$$

$$91 \text{ days} \quad 715 \text{ hog days}$$

715 hog days were used in computing data for this test.

Table 8. Effect of feeding different quantities of shelled corn to 50 gallons of settled slop. All lots had tankage, self fed.

	Lot 1 Corn self- fed. No slop	Lot 2 2 bushels corn	Lot 3 1.5 bushels corn	Lot 4 1 bushel corn	Lot 5 $\frac{3}{4}$ bushel corn
Initial weight per hog	112.	111.	113.	112.	111.
Total gain per hog	109.5	106.0	116.5	113.2	106.0
Daily gain per hog	1.53	1.48	1.63	1.58	1.48
Corn consumed per hog	406.4	356.4	339.7	305.7	252.6
Tankage consumed per hog	42.3	41.0	39.7	42.2	39.3
Settled slop consumed per hog		891.0	1132.5	1528.5	1684.5
Feed consumed per 100 lbs. gain:					
Corn	371.1	336.2	291.6	270.1	233.3
Tankage	38.6	38.7	34.1	37.3	37.1
Settled slop		840.1	972.1	1350.3	1589.2
Grades of the carcasses at a Gov- ernment-inspected plant	9 hard 1 med. soft	5 hard 1 med. hard 4 med. soft	4 hard 2 med. hard 4 med. soft	2 hard 4 med. hard 3 med. soft 1 soft	1 hard 4 med. hard 2 med. soft 3 soft

The second five hogs were slaughtered at the same plant, after 39 days. The combined results are in table 8. Fairly good carcasses were produced with the corn ratio of one bushel per 50 gallons of slop. As the proportion of corn decreased, softness of the carcasses increased, as shown by the results of the carcass gradings made by employees of the packing plant where the hogs were slaughtered and also by the refractive index and iodine number of samples of fat taken from the carcasses. Results of this test indicate that the proportion of corn should be more than one bushel to a barrel of slop.

Table 9. Quality of the carcasses of 25 hogs from the third test, sent to a Government-inspected packing plant.

Lot	No. of hog and sex	Gain in 52 days	Weight day shipped	Packing house grading	Back fat	
					Average refractive index	Average iodine number
Lot 1. Corn and tankage. No slop	1 M	105	265	h	1.4595	61.3
	2 M	100	220	h		
	3 M	75	265	h		
	4 F	75	210	mh		
	5 F	70	190	ms		
Lot 2. 2 bu. corn to each barrel of slop.	6 M	83	205	s	1.4597	64.9
	7 M	105	205	ms		
	8 M	95	235	h		
	9 M	82	235	h		
	10 M	95	240	mh		
Lot 3. 1½ bu. corn to each barrel of slop.	11 M	80	205	ms	1.4599	67.5
	12 M	85	205	ms		
	13 M	85	225	h		
	14 M	95	255	h		
	15 F	105	245	ms		
Lot 4. 1 bu. corn to each barrel of slop.	16 M	92	195	s	1.4599	69.9
	17 F	105	220	s		
	18 M	85	225	mh		
	19 M	105	235	ms		
	20 F	70	215	ms		
Lot 5. 3 pecks of corn to each barrel of slop.	21 M	80	195	s	1.4604	72.4
	22 F	80	200	s		
	23 M	75	255	mh		
	24 M	70	190	mh		
	25 F	90	220	s		

It is evident from this table that as the proportion of slop increased, relative to the corn and tankage, the softness of the carcasses increased.

Kentucky Agricultural Experiment Station

University of Kentucky

SEASONAL MOVEMENTS IN PRICES AND SALES OF BURLEY TOBACCO

BULLETIN NO. 409



Lexington, Kentucky

September, 1940

(401)

CONTENTS

	Page
Sources of data and methods of procedure	40
Historical developments in the seasonal movement of sales . . .	40
Sales in Kentucky, by months	40
Sales in Lexington, by weeks	40
Sales patterns on the Carrollton market	41
Historical developments in the seasonal movement of prices .	41
Prices in Kentucky, by months	41
Prices in Lexington, by weeks	41
Price patterns on the Carrollton market	42
Factors associated with seasonal movement of prices and sales .	42
Long-time factors associated with seasonal movements . . .	42
Short-time factors associated with seasonal movements . .	43
Prices and sales, by grades	45
Seasonal movement of sales	45
Seasonal movement of prices	46
Seasonal movement in other markets than Lexington	46
Size of market	46
Geographical location	46
Summary	47
Tabulated data	47

SEASONAL MOVEMENTS IN PRICES AND SALES OF BURLEY TOBACCO

By **DANA G. CARD** and **CARL M. CLARK**

The price of Burley tobacco often differs from year to year and sometimes marked differences occur within a marketing season. Prices also may differ between markets or localities of production. The nature, cause and extent of these differences are of importance to both buyers and sellers.

Tobacco is grown on about half of Kentucky's farms and Burley tobacco accounts for nearly 40 percent of the cash income received by farmers of the State. For those who grow tobacco year after year, who perhaps in varying amounts, a knowledge of price movements during the marketing season is as important as a knowledge of the conditions which influence prices from year to year. The purpose of this bulletin is to describe the seasonal movements of both prices and sales of Burley tobacco and to point out some of the underlying causes.

The tendency for average prices to differ during the marketing season has stimulated farmers to market their crops at the time when they think prices will be highest. Because this often was early in the marketing season, many growers hired extra labor in stripping and incurred other expenses in rushing their tobacco to market. The net effect was to increase marketing costs for growers, to expand warehouse facilities, and to tax the capacity of receiving and receiving plants. Warehousemen, trucking interests, and the buying companies all had a part in the development of a short, intensive marketing season for Burley tobacco. The shorter season brought with it some advantages, but it also emphasized some problems in both the pricing and physical handling of the crop.

To the buyer, seasonal differences in price offer opportunities for economy in the purchase of raw materials, but they also involve the danger of paying more for supplies than competitors are required to pay. An understanding of the nature and extent of seasonal variations in price, therefore, is desirable for buying and selling interests alike.

Sources of Data and Methods of Procedure

Data from three sources form the basis of this study of seasonal movements in prices and sales of Burley tobacco.

(1) Monthly sales in Kentucky warehouses from 1916 to 1931 are available from reports made to the State Department of Agriculture, Labor and Statistics. These were supplemented with data from a limited number of markets in earlier years.

(2) Sales and prices on the Lexington market, by weeks, from 1909 to date, were tabulated from reports of the market supervisor of sales and from newspaper records. These were supplemented with similar data from the Carrollton, Kentucky, market for several years and with data from nearly all Burley markets during the 1935-36 marketing season.

(3) Data gathered by the Federal Tobacco Market News Service since 1931 furnish additional information on sales and prices, by weeks, especially concerning the grade and quality of tobacco offered for sale.

Marked changes in the volume of tobacco sold and wide differences in price from year to year make it difficult to compare one season with another directly. The distribution of sales during each season, therefore, is expressed in percent of total sales for the season rather than in actual pounds. Prices are used as indexes or relatives based upon the season's average price. The use of these indexes permits the grouping and averaging of years which differ widely in price or volume of sales, without lending undue importance to individual years.

Because prices by grades have been available only in recent years, the major part of the study is based upon prices which are weighted averages of all grades and qualities of tobacco sold. Probably in no other farm product is the range in price between grades so wide as in tobacco. A range from 6 or 8 cents for the lower grades to 30 cents per pound for the top grades is not uncommon. The distribution of tobacco between grades, therefore, may have an important influence upon the weighted average price. The use of average market prices in studying seasonal variation does not permit distinction between price differences due to change in quality and those caused by other price-making forces.

Another shortcoming in the use of weekly data results from the practice of reporting sales by calendar weeks, with no re-

ignition of market holidays. Normally, sales are held five days a week but it frequently happens that the Christmas holiday, which comes at the height of the marketing season, either begins or ends within a calendar week. To improve comparability between seasons, therefore, each succeeding group of five selling days has been used as a week. The adjustments were so made that the weighted average price for the season remained unchanged and the last week of the season carried any odd number of days left over from full five-day weeks. Adjustments were made only in cases where some factor external to the marketing system, such as holidays, governmental action or weather, interrupted the selling.

Historical Developments in the Seasonal Movement of Sales

2 Seasonal movements in the sales and prices of Burley tobacco form dynamic, constantly changing patterns. No one season is adequate to describe the character of the seasonal movements during the 30 years included in this study. Important adjustments have occurred in the length of the marketing season, in the amount of seasonal variation, and in the distribution of sales thruout the season. Much of the variation in the sales of Burley tobacco during the normal marketing season is the result of a gradual historical development. Formerly, sales continued the year around, with the heaviest volume in the spring or early summer. Gradually, however, the seasons have shortened and moved earlier. The introduction of loose-leaf auction selling between 1900 and 1910¹ did much to facilitate early sales. The period under review covers the closing years of an almost continuous hogshead market for Burley tobacco and the years of a gradually shortening season for loose-leaf auction sales. Seasonal differences in price are a counterpart of this development.

In the days of the hogshead market, before the introduction of mechanical rediers, farmers were able to prepare their tobacco in keeping order almost as well as manufacturers. The result was slow, deliberate sales extending thruout the calendar year. With improved means of transportation and particularly with the coming of the loose-leaf auction as a method of marketing, the sales seasons grew shorter.

¹ Mr. Charles W. Bohmer is credited with the construction and operation of the first loose leaf auction warehouse on the Lexington market, under the name of the Burley Loose-leaf Company. Selling began on January 9, 1905.

SALES IN KENTUCKY, BY MONTHS

The distribution of sales in Kentucky warehouses, by month is given in table 1. The gradual shortening of the marketing season from over eight months to less than three months is apparent. In 1938 and 1939, 97 percent of the tobacco was sold in December and January, whereas from 1909 to 1912, about 55 percent was sold in January and February, the two months of heaviest movement. Sales in October, November, March, April and May have been discontinued entirely. During the period, 1909-1912, over 30 percent of the tobacco was sold in these months. Sales in December are influenced by the date on which the market opens but since 1920, they have increased in proportion to the season as a whole. Sales in January increased until 1930, and now between 50 and 55 percent of the crop is sold in that month. February sales grew in importance up to 1917 but have declined since.

Table 1. Monthly distribution of Burley tobacco sold for growers in Kentucky warehouses, for groups of years from 1909 to 1939

	Percent of total sales							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May*
1909-1912**	1.4	5.9	15.1	29.0	25.6	17.6	5.3	.1
1913-1916		.7	15.6	44.1	30.8	7.6	.4	.8
1917-1920		.3	16.0	35.8	35.0	11.5	.6	.8
1921-1926		1.6	26.7	40.7	24.3	6.2	.3	.2
1927-1929		†	29.3	54.7	15.8	.2	†	†
1930-1934			31.1	55.2	12.7	1.0	†	†
1935-1937			40.0	53.3	6.6	.1		
1938-1939			46.7	50.3	3.0			

* Includes sales from May 1 to October 1. ** Based largely on sales in Lexington.
 † Less than .1 of one percent.

A shorter selling season for other types of tobacco also has been developing over an extended period. E. H. Mathewson,¹ writing in 1913 with reference to flue-cured tobacco says, "A marked change has been noted in late years in regard to the time of marketing. Recently, however, there has been noted a tendency to market early, and the bulk of the crop is now often marketed in the first few months of the marketing season". He quotes figures which show that 50 percent of the tobacco from the 1876 crop sold on the Danville, Virginia, market, was sold after May 1 of the following year. Of the 1890 crop, 35 percent was sold after

¹ E. H. Mathewson, *Tobacco Marketing in the United States*, Bureau of Plant Industry Bul. 268, 1913, p. 21.

at date, and of the 1908 crop, less than 3 percent was sold after May 1, 1909. Flue-cured tobacco markets now usually are closed by the first of February.

SALES IN LEXINGTON, BY WEEKS

With the short season in which Burley has been sold in recent years, monthly information is not adequate to describe seasonal movements in either sales or prices. Information by days or weeks is needed.

Lexington is the largest Burley tobacco market and fortunately the one for which data are most readily available. Early in the development of the market a tobacco board of trade was formed for the improvement of trade conditions and the regulation of tobacco sales. Each year a supervisor of sales was appointed whose duty was to see that rules of trading were complied with and to keep a record of prices and the volume of sales. From these records a series of sales and prices by weeks has been built up for each season since 1909.¹

A study of sales by weeks brings out striking changes which have taken place. The length of the marketing season has changed; the distribution of sales and of prices during the marketing season has varied; the range of variation in weekly sales and prices during the season has been much greater some years than others; and the peak of prices or the period of greatest activity in sales has varied from season to season. While in general these changes have been fairly gradual from year to year, they were sufficiently regular to justify an irregular grouping of the seasons for study.

Several factors were considered in determining the grouping of years, but the one given most consideration was the character of the seasonal pattern in each year. There was a strong tendency for seasonal movements, particularly those of prices, to follow a definite pattern for a number of years and then change abruptly. The new pattern then would remain for several consecutive years before another important change would appear. In a number of instances, these changes came at about the time of important adjustments in economic conditions, competitive buying, methods of marketing, activities of cooperative associations, or development

¹ Acknowledgement is made of the kindness of Mr. Ben Bosworth, the present supervisor of sales, in furnishing data for the crops of 1915 to 1920 and 1925 to 1939.

of roads and transportation. These adjustments, also, were given weight in grouping the years of the study into periods. Eight groups of years were selected for the analysis of both sales and prices.

Length of the Marketing Season. The marketing season for Burley tobacco is relatively short compared with that for many agricultural products, but the trend has been definitely toward a shorter selling season. From table 2 it may be seen that since 1909 the marketing season for Burley in Lexington¹ has shortened from an average of 25 to 10 weeks. The seasons have grown shorter at an average rate of 2.4 days per year. The number of weeks required to sell the crops of different years varies with the size of the

Table 2. Length of the tobacco marketing season and average sales per season in Lexington, by periods, 1909 to 1939

Period	Length of season			Sales per season
	Average	Longest	Shortest	
	(Weeks)	(Weeks)	(Weeks)	(1,000 pounds)
1909-1912	25	28	21	38,089
1913-1916	20	25	16	43,557
1917-1920	20	23	15	53,332
1921-1926	17	20	15	19,403
1927-1929	14	15	13	59,566
1930-1934	15	17	13	75,783
1935-1937	11	14	10	64,965
1938-1939	10	10	10	82,547

crop, weather conditions, judgment of the trade as to the outstanding volume of tobacco, etc., so that sales seasons have not always grown shorter from year to year. The pronounced trend toward shorter seasons is apparent, however. The longest marketing season was 28 weeks, in 1910, and the shortest, 10 weeks, in the past four years, or a difference of 18 weeks.

Extent of Variation in Sales. While the sales season has declined to about two-fifths of its former length, the total volume of sales on the Lexington market has a little more than doubled (Table 2.) The increase in volume was due chiefly to greater total production of Burley tobacco but partly to a growth in the relative importance of the market. In recent years, however, sales in Lexington have consistently amounted to between 20 and 25 percent

¹ During most of the period included in this study, Lexington was the first loose-leaf Burley market to open and the last to close. The hogshead market stayed open the year around.

If the total production of Burley tobacco. Average sales per week, therefore, have increased considerably and greater variation in the volume sold from week to week is possible.

Average sales per week, when expressed in percent of the season's total, increased from four percent in 1909-1912 to ten percent in 1938 and 1939. (Table 3.) The relationship between the average week and the weeks of heaviest volume is relatively constant, however, because in each period the volume handled at the peak of the season was about twice as large as the average for the season as a whole. Nearly six times as much tobacco was sold in the three weeks of heaviest movement as in the average week.

Table 3. Sales of tobacco during the average week, the peak week, and the three highest weeks, on the Lexington Market, and the average deviation of weekly sales, in percent of the total sales for the season, by periods, 1909 to 1939

Period	Average week	Peak week	Three highest weeks	Average deviation in weekly sales
	(Percent)	(Percent)	(Percent)	(Percent)
1909-1912	4.0	8.5	24.6	2.7
1913-1916	5.1	11.2	31.2	3.5
1917-1920	5.2	11.2	31.6	3.6
1921-1926	5.8	12.2	33.4	3.3
1927-1929	7.2	12.6	36.4	4.2
1930-1934	6.9	13.4	38.6	4.8
1935-1937	9.0	18.1	50.0	5.9
1938-1939	10.0	18.3	52.7	6.4

The extent of variation in the weekly volume of sales, too, has remained in proportion to the growing volume of business. The average deviation in weekly sales was roughly two-thirds of the average weekly volume in each period. Recognizing trends in the volume of sales and in the length of season, therefore, the extent of variation in sales per week may be said to have remained relatively constant.

Distribution of Sales. An important characteristic of the seasonal pattern in the early years was the relatively long period of stability in the rate of selling. Sales increased rapidly after the opening of the season and then remained fairly constant for a time before beginning a slow decline for the rest of the season. This characteristic was an important part of the seasonal movement until 1920. Since then the period of stability in the volume of sales per week has diminished until almost completely lost in recent years. (Figure 1.)

Since 1909-1912, sales have shifted forward with a decided increase in the importance of the first quarter of the marketing season and corresponding declines in the third and fourth quarters. In 1909-1912, approximately 13 percent of the total sales occurred in the first quarter, 41 percent in the second quarter, 38 percent in the third quarter, and 8 percent in the fourth quarter. (Table 4.) By 1938-1939, first-quarter sales had increased to 40 percent, third-quarter sales had decreased to 17 percent, and fourth-quarter sales to 2 percent. Little or no change had occurred in the percent of tobacco sold during the second quarter of the season.

Table 4. Percent of tobacco sold during the first, second, third, and fourth quarters of the marketing season in Lexington, by periods, 1909 to 1939

Period	First quarter	Second quarter	Third quarter	Fourth quarter
	(Percent)	(Percent)	(Percent)	(Percent)
1909-1912	12.7	41.0	38.0	8.3
1913-1916	25.1	47.9	22.6	4.4
1917-1920	32.2	44.4	22.6	0.8
1921-1926	34.3	39.5	22.5	3.7
1927-1929	29.1	41.5	27.6	1.8
1930-1934	39.3	42.4	17.2	1.1
1935-1937	40.0	41.6	16.8	1.6
1938-1939	39.3	42.0	17.0	1.7

The shift of sales to the early part of the season has resulted in a complete disappearance of the period of low sales characteristic of the opening weeks of the marketing season in the first years of the study. (Figure 1.) The percent of the season's total sales which occurred in the opening week increased from only 0.4 percent in 1909-1912 to 13.2 percent in 1938-1939. The percent of sales occurring in the opening week during recent years was larger than the percent of sales occurring in the weeks of heaviest movement in the early years of the study.

Unlike the opening weeks, the weeks of low sales at the close of the season have remained a part of the seasonal pattern even tho they have declined in number. Weeks with sales of less than 1 percent of total sales declined from 7.3 weeks in 1909-1912 to 2.0 weeks in 1938-1939. (Table 5.) The decrease in the number of weeks of low sales at the end of the marketing season was an important factor in reducing the total length of marketing season

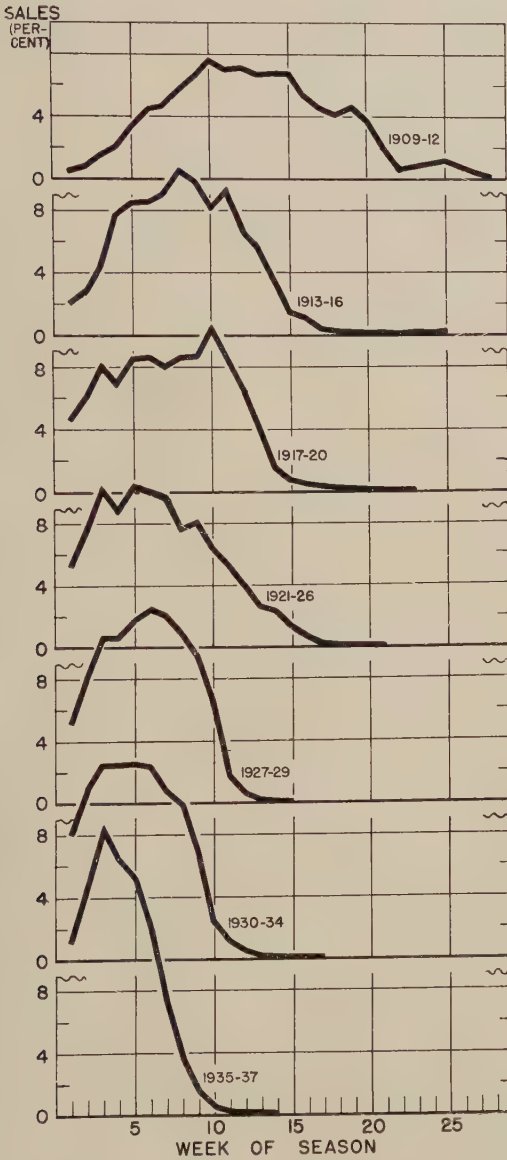


Figure 1. Weekly sales of Burley tobacco on the Lexington Market, in percent of total sales for the season, by periods, 1909-1937.

Marketing seasons have become progressively shorter and sales have reached their peak earlier in the season.

similar changes took place. Data which were obtained for a number of years, relative to the Carrollton market, bear out this assumption.¹

Table 7. Cumulative weekly sales of Burley tobacco on the Lexington Market, in percent of the season's total, by periods, 1909 to 1939

Week of season	Year							
	1909- 1912	1913- 1916	1917- 1920	1921- 1926	1927- 1929	1930- 1934	1935- 1937	1938- 1939
	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
1	.41	2.09	4.60	5.22	5.21	7.93	11.13	13.20
2	1.19	4.93	10.61	12.62	13.34	18.68	25.78	30.13
3	2.73	9.39	18.90	22.71	23.94	31.14	43.97	48.42
4	4.75	17.12	25.54	31.43	34.51	43.65	60.31	65.89
5	8.17	25.66	34.03	41.79	46.23	56.26	75.39	81.23
6	12.58	34.12	42.67	51.86	58.66	68.63	87.21	91.93
7	17.26	43.12	50.64	61.50	70.61	79.38	94.31	97.33
8	22.85	53.64	59.26	69.09	81.52	89.20	97.67	99.19
9	29.43	63.39	67.93	77.10	90.92	95.86	99.16	99.83
10	36.88	71.51	78.26	83.42	97.47	98.19	99.68	100.00
11	43.81	80.68	86.60	88.66	99.18	99.32	99.87	
12	50.84	87.46	93.18	92.65	99.81	99.77	99.95	
13	57.49	92.91	97.07	95.33	99.93	99.90	99.97	
14	64.21	96.46	98.55	97.64	99.98	99.94	100.00	
15	70.93	97.88	99.28	98.95	100.00	99.992		
16	76.11	98.87	99.70	99.65		99.998		
17	80.67	99.19	99.87	99.89		100.00		
18	84.77	99.37	99.94	99.97				
19	89.32	99.44	99.96	99.99				
20	93.03	99.49	99.98	100.00				
21	94.99	99.58	99.995					
22	95.71	99.61	99.997					
23	96.52	99.75	100.00					
24	97.49	99.84						
25	98.65	100.00						
26	99.46							
27	99.85							
28	100.00							

The seasonal patterns of sales in Carrollton from 1913 to 1920 were very similar in amount of variation, to those in Lexington and also in the seasonal distribution of sales and the length of the marketing season. (Figure 3.) The Lexington market had a longer season, but the extra length was largely of weeks of low sales which were of little importance in the total volume. The weeks of low sales at the end of the season never were an important part of the seasonal pattern for Carrollton because when sales declined rapidly at the end of the season the market was closed.

¹ Acknowledgement is made of the kindness of Mr. R. M. Barker of Carrollton in furnishing data relative to that market.

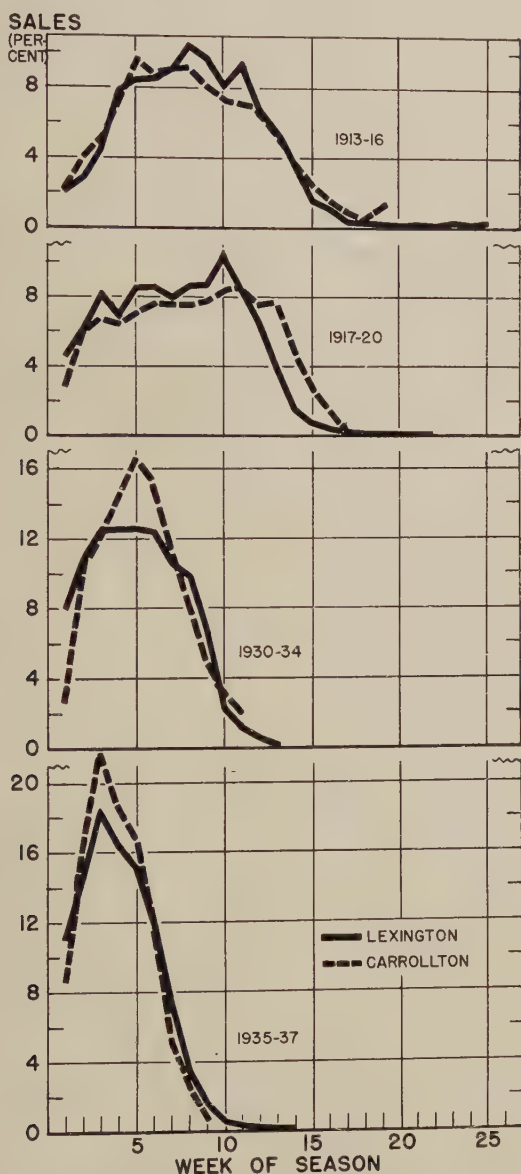


Figure 3. Weekly sales of Burley tobacco on the Lexington and Carrollton markets, in percent of total sales for the season, by periods, 1913-1920 and 1930-1937.

Prior to 1920, the distribution of sales in the two markets was similar but since 1930 the peaking of sales has been more pronounced in the Carrollton market.

During the years from 1930 to 1937, sales on the Carrollton market were slower in getting under way than in Lexington but, once under way, they were more rapid, relatively, and the marketing season ended more abruptly. The period of rather stable selling characteristic of both markets from 1913 to 1920, disappeared in a more extreme peaking of sales on the Carrollton market than on the Lexington market. In 1930-1934, 17.1 percent of the sales of the Carrollton market occurred during the week of heaviest sales.

Table 8. Average number of weeks in the tobacco marketing season, the number of weeks to the peak of sales, the percent of total sales in the opening week and in the peak week, and the number of weeks with less than one percent of sales, on the Carrollton and Lexington markets, 1913 to 1937

Period	Number of weeks			Percent of season's total sales	
	in the season	to the peak of sales	with less than 1 percent of total sales	Opening week	Peak week
	(Weeks)	(Weeks)	(Weeks)	(Percent)	(Percent)
Carrollton Market					
1913-1916	17	8	0.3	2.2	10.6
1917-1920	15	8	0.2	2.8	9.9
1930-1934	11	4	0.2	2.8	17.1
1935-1937	8	3	0.0	8.6	22.0
Lexington Market					
1913-1916	20	10	2.4	2.1	11.2
1917-1920	20	8	1.5	4.6	11.2
1930-1934	15	4	1.4	7.9	13.4
1935-1937	11	3	1.0	11.1	18.1

In 1935-1937, 22 percent of the tobacco was sold during the peak week. Corresponding figures for the Lexington market were 13.4 percent and 18.1 percent, respectively. (Table 8.) In general, however, seasonal movements were similar in the two markets.

Historical Developments in the Seasonal Movement of Prices

Changes in the seasonal marketings have been accompanied by similar changes in the prices paid for Burley tobacco. With perishable crops and some non-perishable ones, prices usually bear an inverse relationship to the volume of sales; but with Burley tobacco heavy movements to market coincide quite closely with the highest prices of the season. As seasons have become shorter and sales more concentrated, average prices have become more variable at least until the last two seasons.

PRICES IN KENTUCKY, BY MONTHS

Market prices in Kentucky, by months, expressed in percent of the weighted average price for each season, are given in table 9. Definite trends in the relationships between months are shown. In general the change has been toward lower prices in the months

Table 9. Monthly prices of Burley tobacco sold for growers in Kentucky warehouses, in percent of the season's average price, by months, for groups of years from 1909 to 1939

Period	Percent of season's average price							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May
1909-1912*	88	90	97	106	99	94	86	
1913-1916		90	99	102	99	92	85	87
1917-1920		88	108	102	97	77	60	67
1921-1926		99	102	103	97	86	65	50
1927-1929		59†	98	105	84	57	41†	32†
1930-1934			111	99	79	62	47†	
1935-1937			114	96	60	30		
1938-1939			98	102	90			

* Based largely on sales in Lexington.

† Based on less than .1 of one percent of the season's sales.

near the end of the marketing season and toward higher prices in the months of December and January. The trend in marketings has been toward these months too, so the peak of sales and the peak of prices have tended to coincide in the center or early part of the marketing season.

PRICES IN LEXINGTON, BY WEEKS

Seasonal price movements not only have changed considerably over the past quarter of a century, but these changes, in turn, have influenced the pattern of sales and have helped to create many problems in receiving, pricing and selling tobacco. Shorter marketing seasons have meant fewer price quotations and a more limited period during which growers could sell their tobacco. They also have meant a shorter period during which changes in business conditions, foreign trade, international relations, etc., might affect prices.

Extent of Variation in Prices. Variation in prices during the marketing season has tended to become greater. The average fluctuation of weekly prices, above and below the annual average, was approximately 10 percent in 1909-1912, 7 percent in 1913-1916, but 9 percent in 1935-1937. (Table 10.) Prices in 1938-1939 were more stable and varied an average of less than 7 percent.

The range from the lowest to the highest weekly price of the season was 37 percent of the average annual price in 1909-1912 compared with 87 percent in 1935-1937. Approximately 24 and 63 percent, respectively, of these ranges were between the annual price and the lowest price; and 13 percent and 24 percent, respectively, between the annual price and the peak price. The years from 1917 to 1920 were out of line with the long-time trend in extent of seasonal fluctuations in Burley prices. This probably was due largely to the economic repercussions of the World War.

Table 10. Average deviation of weekly prices of Burley tobacco sold on the Lexington Market, the range in price from the lowest to highest, from average to highest and from average to lowest, expressed in percent of the season's average price, by periods, 1909 to 1939

Period	Average deviation of weekly prices	Range		
		from lowest to highest	from annual average	
			to highest	to lowest
	(Percent)	(Percent)	(Percent)	(Percent)
1909-1912	10	37	13	24
1913-1916	7	29	8	21
1917-1920	23	78	21	57
1921-1926	10	41	8	33
1927-1929	14	56	12	44
1930-1934	23	76	15	61
1935-1937	29	87	24	63
1938-1939	7	21	7	14

Changes in the Character of Seasonal Price Movements. The seasonal movement of Burley prices may be divided into three segments or periods: first, a period with weekly prices moving upward from the opening of the season; second, a period with prices remaining at a relatively high, stable level; and third, a period with prices declining until the close of the selling season. The relative importance of these segments has changed materially during the past thirty years.

Approximately one-fifth of the marketing season was included in the period of rising prices during the years from 1909 to 1912 (Table 11.) Since 1909-1912, this part of the seasonal movement of prices has grown shorter and in some years has been wholly absent. (Figure 4.)

The period of relatively high, stable prices also changed ma

erially. It first moved earlier in the marketing season but in most years since 1926 was displaced entirely by rising and subsequent

Table 11. The number of weeks with prices of Burley tobacco rising to, remaining above, and declining below the annual price, on the Lexington Market, 1909 to 1939

Period	Length of season	Weeks with prices		
		rising to annual price	remaining above annual price	declining below annual price
	(Weeks)	(Number)	(Number)	(Number)
1909-1912	25	5	10	10
1913-1916	20	3	6	11
1917-1920	20	4	7	9
1921-1926	17	1	9	8
1927-1929	14	3	5	6
1930-1934	15	0	7	8
1935-1937	11	0.3	4	7
1938-1939	10	1.5	4	4.5

falling average market prices. With this change the week of highest prices shifted forward in the season. In 1909-1912 the peak of prices occurred when approximately 45 percent of the marketing season had passed; but in 1935-1937, the peak price came in the third week when only about 24 percent of the marketing season had passed. (Table 12.)

Table 12. Number of weeks and percent of the season from the opening week to and including the week of highest prices paid for Burley tobacco in Lexington, by periods, 1909 to 1939

Period	Length of season		
	Total	From opening to week of highest price	
	(Weeks)	(Weeks)	(Percent of season)
1909-1912	25	12	45
1913-1916	20	6	34
1917-1920	20	8	40
1921-1926	17	5	27
1927-1929	14	6	41
1930-1934	15	3	18
1935-1939	11	3	24
1938-1939	10	3.5	35

The peaking of prices at relatively higher levels earlier in the marketing season resulted in the seasonal movement becoming largely one of declining prices. This was accompanied by a tendency for weekly prices to decline to lower levels each season until 1938. It is this decline in the third phase of the pattern that accounts for

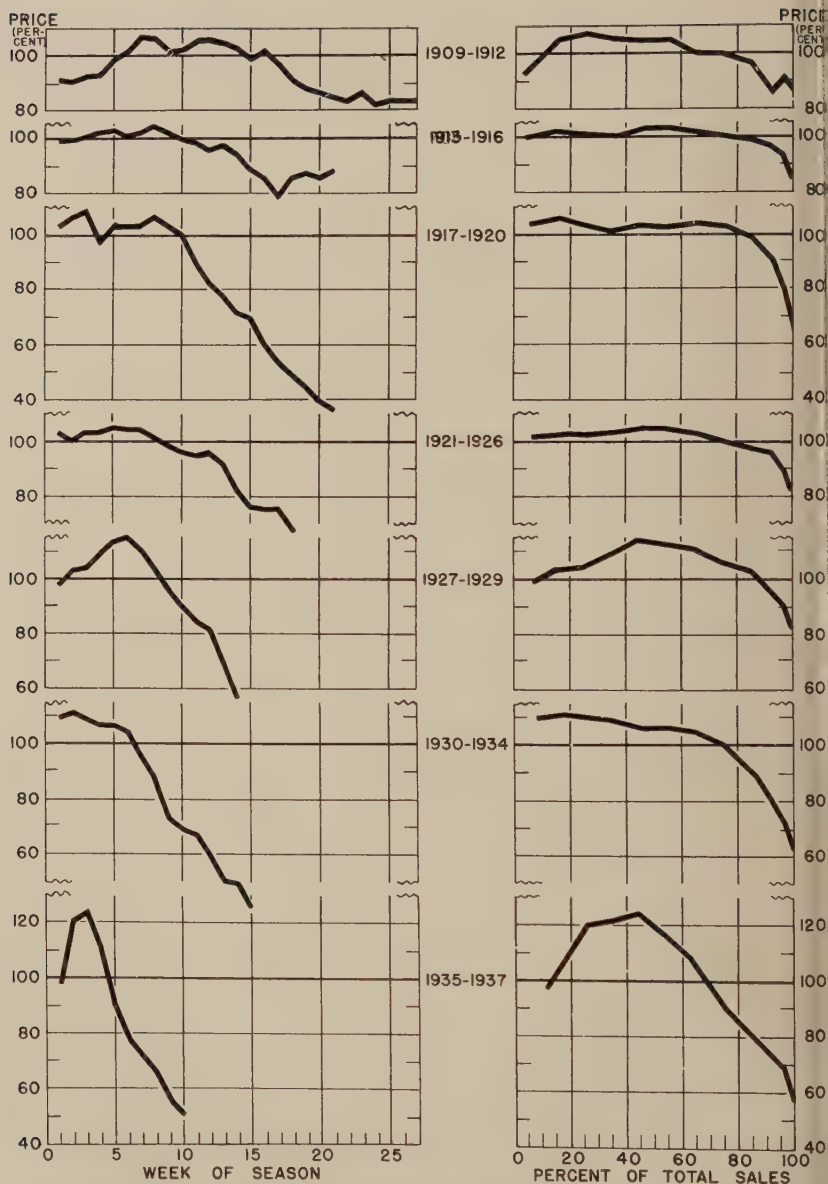


Figure 4. Prices of Burley tobacco sold on the Lexington Market, in percent of the season's weighted average price, by weeks (left) and by accumulated percentage of total sales (right), by periods, 1909-1937.

Sharp declines in prices usually occurred only after about 80 percent of the crop had been sold.

most of the increase in the amount of seasonal variation of Burley prices. In 1913-1916, prices in nearly 50 percent of the weeks were within 5 percent of the annual price. (Table 13.) Less than 10 percent of the weekly prices were within this range in 1935-1937. In 1938-1939, however, prices were unusually stable.

Table 13. Percent of the marketing season with weekly prices within five percent of the season's average price, by periods, 1909 to 1939

	1909- 1912	1913- 1916	1917- 1920	1921- 1926	1927- 1929	1930- 1934	1935- 1937	1938- 1939
Percent	37	49	21	38	26	20	8	35

Seasonal Prices in Relation to Volume of Sales. The violent changes in the seasonal movement of Burley prices, shown on the left of figure 4, are somewhat modified when prices are related to the volume of sales rather than to weeks in the season. On the right hand side of figure 4 prices are plotted against the total sales to date, each week during the marketing season. This tends to eliminate the effect of the bunching of sales at the beginning of the season.

Except in the period, 1935-1937, very little fluctuation occurred in weekly prices until after 80 percent of the sales had been completed. In most periods, prices did not fall below the average for the season until 75 to 80 percent of the crop had been marketed; but in the period, 1935-1937, prices started falling when 45 percent had been sold and fell below the season's average price when 70 percent of the tobacco had been marketed. This was due largely to extreme fluctuations in the prices paid for the 1936 crop. It appears that the bulk of sales usually are made before drastic price declines set in but the late-season decline in prices increased in importance until 1938.

PRICE PATTERNS ON THE CARROLLTON MARKET

Historical adjustments in the Carrollton market have followed very closely the seasonal changes that have occurred in prices at Lexington. (Figure 5.) The amount of seasonal variation has been greater on the Lexington market, but mainly in the extent that prices in Lexington declined in weeks after the Carrollton market was closed.

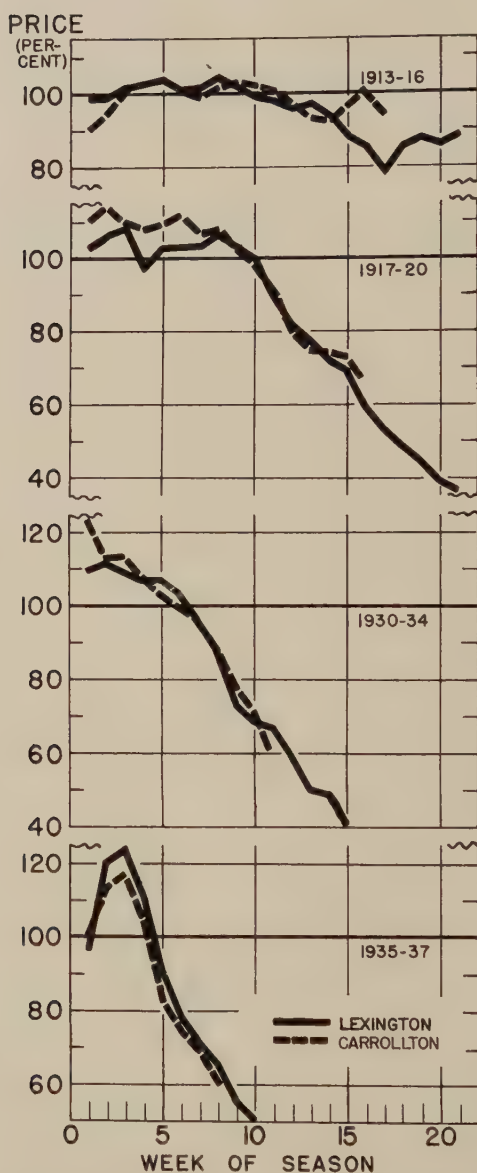


Figure 5. Weekly prices of Burley tobacco sold on the Lexington and Carrollton markets, expressed in percent of the season's weighted average price for each market, by periods, 1913-1920 and 1930-1937.

Prices in Lexington and Carrollton moved very much alike in each period.

Factors Associated With Seasonal Movements of Prices and Sales

Many factors are associated with the developments that have occurred in the seasonal movements of Burley prices and sales during the past thirty years. Most of these cannot be measured quantitatively as to their relative influence in bringing about the changes which have taken place. Adequate data for this purpose are not available. Causes frequently are closely inter-related, thus increasing the complexity of the problem of evaluating the relative importance and influence of each. The discussion here, therefore, will be largely a qualitative treatment of the manner in which certain factors probably brought about changes in the seasonal movements of both prices and sales.

In general, the organization and structure of the system for marketing Burley tobacco have changed very little during the period of this study. Considerable change has occurred, however, in marketing methods and practices, in size and number of market facilities, in the efficiency of performing various marketing functions, and in such other phases of the industry as the amount and location of production, buying forces on the market, and consumer demands. Most of the changes associated with and accounting for variations in the seasonal movements of prices and sales may be grouped under the two general headings, long-time factors and short-time factors.

The average quality of tobacco offered for sale was one of the most important single factors influencing market prices from week to week in recent years. It is both a long-time and a short-time factor and likewise is intimately associated with prices by grades. Quality, in its various aspects, therefore, will be discussed under these headings.

LONG-TIME FACTORS ASSOCIATED WITH SEASONAL MOVEMENTS

The steady but pronounced adjustments that have occurred in seasonal patterns over the past 30 years would indicate that certain underlying factors have constantly exerted an influence on the seasonal movement of both sales and prices. These are classified as long-time factors and include improvements in transportation, growth in market capacity, average weight per basket, changes in

the type of tobacco grown, competition between warehouses, competitive buying by manufacturers, and the cumulative effect of higher prices early in the season, once such a movement was started.

Improvement in Transportation Facilities. The ways and means of transporting tobacco from the farm to the auction market have been improved materially since 1909. An important part of this improvement was the building of hard-surfaced roads, followed by the use of trucks. In the early years of the study, tobacco was moved to market by horse and wagon. Streets in the warehouse district lined with wagons waiting to be unloaded were a common sight in the early market centers. Practically all the tobacco sold on the Lexington market now is delivered by truck. Commercial truckmen have entered the field and provide an important part of trucking facilities for moving tobacco to market. These changes contributed to the shortening of the marketing season and the peaking of sales in the early part of the season. The time required for making deliveries has been materially reduced, leaving farmers more time at home to strip and prepare tobacco for market. Tobacco also can be moved greater distances to market with less inconvenience and cost than formerly. Improvements in transportation, therefore, have placed farmers in a better position to make deliveries rapidly and at times when prices appear most favorable.

Increased Capacity for Auction Selling. A number of conditions contribute jointly to the ability of a market to receive and sell tobacco. The more important of these are the number and size of auction warehouse floors, the number of sets of buyers, and the rate of sales maintained per hour. These factors combined with length of sales day give a fairly accurate measure of the capacity of a market to receive and sell tobacco. The weight of tobacco per basket also influences sales volume. This varies with the condition of the tobacco, the size of individual crops, and the number of grades into which the tobacco is sorted.

In the early years of loose-leaf-auction selling, poor roads and delivery by wagon greatly limited the area served by a given tobacco market and competition between warehouses was confined largely to those within a market. Auction floors operated independently of each other and with few or no restrictions from the

overnment or trade organizations. The coming of better roads and more rapid transportation by truck served to bring several market centers within reach of individual farmers. They also enhanced the opportunity for warehousemen to enlarge their business by attracting deliveries from territory formerly served by other markets. As a consequence, trade areas expanded and overlapped. It then became necessary for tobacco warehousemen to work more closely together for their own interest.

In time, tobacco boards of trade were established for the purpose of more effectively promoting the interest of each market. Efforts of the boards of trade centered largely around improvements in the services rendered by the auction floors. These included the elimination of unfair trade practices, standardization of sale procedure, reduction of destructive competition among warehousemen, establishment of uniform commission charges within the market, solicitation of help from merchants and commercial services in attracting farmers to the market, and last but not least, development of facilities which help the market as a whole to receive, sell and pay for tobacco. The success of efforts in the latter instance has contributed materially to the historical adjustments that have occurred in the seasonal pattern of sales.

Competition between markets doubtless in time would have eliminated some markets but the Burley Tobacco Grower's Cooperative Marketing Association, which was organized in 1921, bought or leased most of the warehouses in the smaller markets. When the Association ceased operations in 1927, many of these markets lacked representation of enough buying interests to justify re-opening as auction markets. This permitted substantial growth in the markets which had stayed open for auction selling, as illustrated by the fact that in 1917 and 1918 Burley tobacco was sold in more than 40 markets in Kentucky but in 1937, 1938 and 1939, only 22 Burley markets operated in this State. The volume of tobacco handled, however, increased nearly 40 percent during this period.

The sale capacity of the Lexington market increased greatly during the period of this study. While the sales season shortened from over 25 weeks to about 10, the volume of sales increased from about 38 million pounds per year to over 80 million. (Table 2 and

figure 8.) The doubling of sales in 30 years, while cutting the season to less than half its former length, was possible only thru the expansion of market facilities.

Starting with eight warehouse sale floors in Lexington during the period, 1909-1912, more warehouses were built until 25 houses were holding regular sales during the 1938 and 1939 crop seasons. (Figure 6.) Not only were more houses built but existing ones were enlarged to handle more tobacco in a given period.¹ A practice

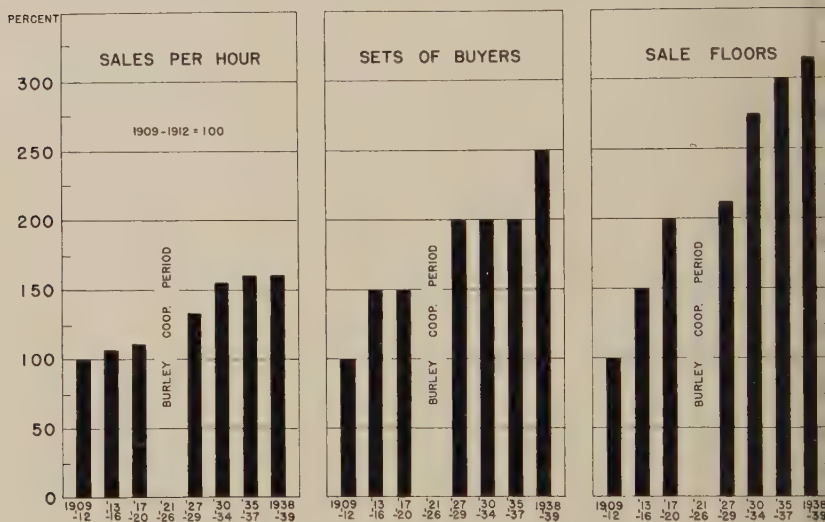


Figure 6. Index of basket sales per hour, number of sets of buyers, and number of auction sale floors on the Lexington Market, by periods, 1909-1939. (1909-1912=100).

The speed of sales increased over 50 percent, the sets of buyers 150 percent and the number of sales floors over 200 percent from 1909-1912 to 1938-1939.

of rotating sales between houses in Lexington stimulated this growth because each warehouse got only five or six full sales per season and the larger the floor space in an individual warehouse, in proportion to that of the whole market, the larger the annual volume of business for the warehouse. Setting minimum commission charges for selling tobacco also enhanced the importance of volume of business in determining profits from warehouse operation. This undoubtedly did much to encourage warehouse

¹ Data on square feet of floor space on the Lexington market are not available for the period of the study.

construction, to encourage the sale of larger piles of tobacco and, indirectly, to create demand for more sets of buyers.

The number of sets of buyers on the Lexington market has more than doubled since 1909. Under the loose-leaf auction method of sale, an auctioneer, a warehouseman, and a group of buyers representing the manufacturers and dealers interested in the market, constitute a marketing or sales unit. The amount of business which such a group can transact in a day apparently is limited to about a half million pounds of tobacco. The volume of the entire market, therefore, is limited by the number of sets of buyers who operate on the market. Most of the smaller markets have only one set of buyers but the larger markets have more. During the years, 1909-1912, two sets of buyers worked the Lexington market. As volume grew, more buyers were added so that from 1927 to 1936, four sets were making purchases regularly. In 1937 a fifth set of buyers was added. These changes have contributed materially

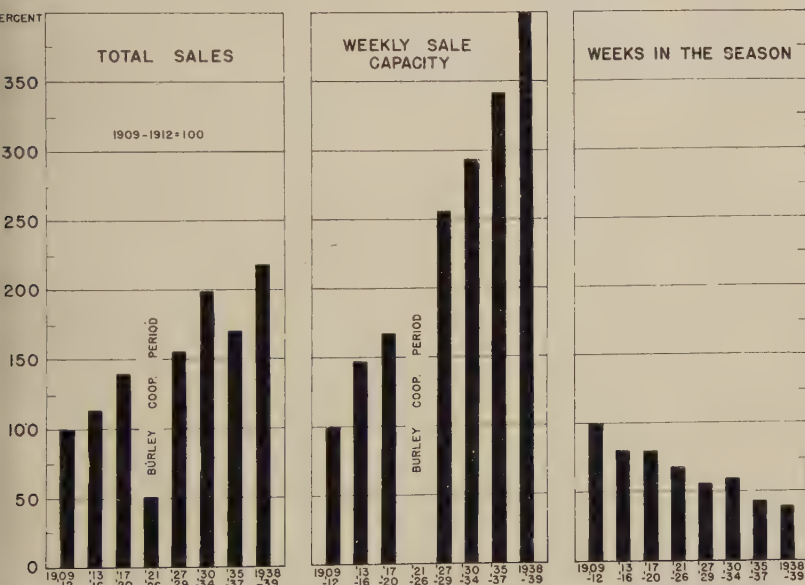


Figure 7. Index of total sales, maximum weekly sale capacity, and number of weeks in the selling season on the Lexington Market, by periods, 1909-1939. (1909-1912=100).

While the volume of sales more than doubled and the season was reduced to less than half its original length, the weekly basket sales capacity of the market increased to four times that of the period, 1909-1912.

to the ability of the market to move tobacco into the channels of trade.

The rate at which sales are made also influences the volume of tobacco sold each week. As the loose-leaf method grew, buyers and auctioneers became more highly trained and farmers learned better how to strip and handle their tobacco. All this worked toward speeding up sales. In the early years of the loose-leaf system, 200 to 225 baskets per hour was a common rate of selling tobacco.¹ The present board of trade rules in Lexington, Kentucky, call for sales at the rate of 360 baskets per hour. The rate of sale, therefore, has been increased about 60 percent. (Figure 6.)

The combined effect of more sets of buyers and greater rapidity of sales is illustrated in the center of figure 7. The estimated² sale capacity of the market in 1909-1912 was 12,375 baskets per week and 49,500 baskets in 1938-1939, or an increase of 300 percent. Estimated sale capacity increased more than the total volume of sales on the market. In the period from 1930 to 1934, total sales were nearly twice as large as in 1909-1912; but the estimated sale capacity had increased to nearly three times the capacity existing in 1909-1912. Since 1934, sale capacity has continued a more rapid upward trend than total sales. The increase of sale capacity has been an important factor in reducing the number of weeks in the marketing season. The reduction in the time required to sell the tobacco delivered to the Lexington market is illustrated graphically by years in figure 8.

The trend in the amount of tobacco sold in Lexington, though fluctuating widely from year to year, was generally upward during the period of this study. Actual market capacity, measured in terms of the average pounds sold per week for the three highest weeks of the season, followed closely the trend in the total pounds sold, until the organization of the Burley Tobacco Association in

¹ Data on rates of sale for the periods during and before the World War are not to be termed as official but rather as estimates of the actual rates of sale. Data available indicate that no official standard was set during the early years of the auction market.

² The capacity of the market was estimated by determining the number of baskets that could be sold in a week. The basket sale rate per hour times the number of selling hours per day times the number of sets of buyers times five selling days per week equals the basket sales per week. This does not represent the actual sales per week, but more nearly the possible maximum sales of the market operating at full capacity. Actual sales per week would be less since in some weeks the market does not have sufficient volume for full-time operation. The length of the selling day has varied only slightly and was estimated to be 5½ hours throughout the period of the study.

1921.¹ For the period as a whole, however, market capacity grew more rapidly than total sales, hence shortening the sales season was possible. Auction sales were much reduced during the life of the Burley Association but an upward trend persisted thruout.

From 1909 until 1920, annual sales increased at an average rate of about two million pounds per year. Since 1926, volume has increased only a little over one quarter of a million pounds per year. The growth in weekly market capacity was more steady thruout the period. It increased 278,000 pounds per year from 1909 to 1920 and 240,000 pounds per year from 1926 to 1936. The sharp increase from 1936 to 1937 and 1938 was not used in calculating

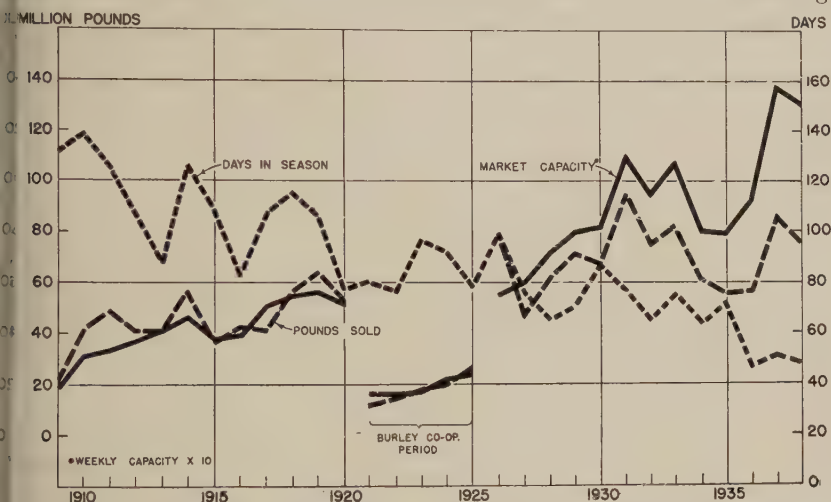


Figure 8. Pounds of Burley tobacco sold in Lexington, the approximate weekly market capacity and the number of days on which the market operated, by years, 1909-1938.

Both annual and weekly sales increased but the marketing season grew shorter by 2.4 days per year. Market capacity increased more rapidly than total sales, especially after 1926.

this trend. In recent years, particularly, market capacity has outstripped the growing volume of sales.

The number of days in the marketing season also fluctuated from year to year but the trend was steadily downward. The marketing season was 138 days in 1910 but since 1935 only 45 or 50 days were required to dispose of nearly twice the amount of tobacco

¹ Market capacity has been multiplied by ten for easy comparison with total sales on the market. (Figure 8.)

sold in the first years of the study. Such opposite changes could come about only by materially increasing the capacity of the market for selling tobacco. The increased capacity was accomplished largely by speeding up sales, increasing the number of sets of buyers, and possibly from increasing the average weight of the baskets of tobacco sold.

Table 14. Pounds of tobacco sold on the Lexington Market, in percent of all loose-leaf sales of Burley tobacco, by periods, 1909 to 1939

	1909- 1912	1913- 1916	1917- 1920	1921- 1926	1927- 1929	1930- 1934	1935- 1937	1938- 1939
Percent	18	20	18	18	23	21	22	22

Some of the increase in annual volume of sales at Lexington was at the expense of other Burley markets, but to a large extent it was due to increased production of Burley tobacco. The proportion of the Burley crop sold in Lexington varied from 15 percent to 27 percent in individual seasons but no pronounced trend is apparent. (Table 14.) In recent years about 22 percent of the total crop has been sold in this market.

Weight per Basket. The average weight per basket of tobacco offered for sale influences the volume of tobacco which moves thru the market in a given time. Adequate data with which to measure the long-time trend in weight per basket have not been obtained but a comparison of the pounds actually sold per week with the number of baskets which theoretically should be sold, gives a rough idea of the weight per basket. In the early years of the study, sales at the height of the season averaged about 250 pounds per basket of theoretical sale capacity in Lexington.¹ In recent years the average has been about 260 pounds per basket. Weight per basket in individual years varied from just under 200 pounds to over 300 pounds, but little or no trend in weight per basket is shown. There are reasons to believe, however, that the average weight per basket has increased over the thirty-year period. Among these are the following. (1) Producers have larger crops than formerly and larger quantities can be delivered at one time by truck than was possible with wagons. (2) The type of Burley grown in recent years lends itself to the use of fewer grades than did the earlier type of Burley tobacco. (3) The urge of warehouse-

¹ Sales rate per hour times the number of hours of selling.

men to get as many pounds as possible on the floor at one time seems to have become greater. It is probable, therefore, that increased weight per basket has been important in increasing the market's capacity to sell tobacco.

Weight per basket appears to vary considerably during the marketing season. During the last five years, the average basket in several Lexington warehouses weighed 172 pounds for the first sale of the season, 271 pounds for the second sale, 283 for the third, 210 for the fourth, and 170 pounds for the fifth full sale in the season. These weights do not correspond to consecutive weeks of the marketing season but cover a period of five to seven weeks. Incomplete sales at the end of the season were not considered in the calculations. The figures may exaggerate seasonal differences in the weight per basket because in making the calculations it was assumed that all basket space was filled for each sale, which may not have been true early in the season. Neither was allowance made for rejected tobacco which often is highest during the first sales. The figures indicate, however, that much of the peaking of sales at the height of the marketing season may be accomplished by putting more tobacco on each basket and so increasing the pounds sold per hour. Large baskets at the height of the season doubtless are largely the result of large individual crops being sold at that time.

Changes in Competitive Buying Conditions. Competition in buying may affect seasonal changes in the price of Burley tobacco, but no statistical evidence was compiled on this point. With each marketing season separate and distinct from the preceding one and yet so short in duration, the adjustment of prices to the various influences of supply and demand must take place quickly. Prior to the opening of the markets little seems to be known about the prices which will be offered. Buyers, therefore, must feel each other out in the opening stages of the market, the average quality of the crop as it appears on the warehouse floors must be judged, and its weight and ultimate yield estimated. Some information already is available but at no earlier time has so large a sample of the crop been assembled upon which to base judgment. The opening days of each marketing season are ones of experimentation and adjustment. It is not surprising that this frequently is a period of rising prices as each buyer bids a little higher than he thought he might have to for a particular grade of tobacco. If

supply has been underestimated, prices naturally will decline from the start, as they have in some years. (Figure 10.)

This line of reasoning can explain the early seasonal rise of recent years only on the ground that longer seasons in the early years, with slower sales, permitted the adjustments to take place with less influence upon price. Competitive adjustments to market conditions should be recognized, but no exact statement can be formulated as to what competition has contributed to the character of the seasonal movement of Burley prices until better information is available.

There are reasons to believe, however, that competition on the buying side of the market has been a factor in the historical adjustments which have taken place. Some competitive factors now operating probably did not exist in the earlier years of loose-leaf selling. For example, the American Tobacco Company was the principal buyer of Burley tobacco from 1909 to 1912. In these years prices varied about as little thru the season as in any period in the history of the Lexington market. The court decision, dissolving the American Tobacco Trust, tended to break the monopoly into companies with each organized to produce certain brands of tobacco products. The several companies, therefore, would not, necessarily, come into direct competition with one another in buying the grades of tobacco needed for the production of their special products. The seasonal price pattern in 1913-1916 differed little from that which existed during the life of the American Tobacco Trust except that weekly prices declined lower at the end of the marketing season in the later period.

The several companies formed out of the American Tobacco Trust did not continue to confine their production to a limited line of products, however, and the tendency, except for the snuff companies, was to broaden the production program to include a wider range of tobacco products. The World War of 1914-1918 was important in popularizing cigarette smoking and setting into motion a demand that has definitely affected the history of the Burley tobacco industry. The increased demand for cigarettes probably encouraged some companies to add this product to their line of production. Cigarette companies may have added other types of tobacco products in order to utilize various grades of

tobacco more efficiently, or competition in selling may have forced the several companies to broaden their lines of products in order to reduce selling costs.

The wider the range in the type and quality of raw tobacco needed for processing by the various companies the more they were brought into direct competition on the auction floor. This adjustment apparently was going on in the decade after 1920; but the seasonal variation in prices was less pronounced from 1921 to 1926 than in either the preceding or the following period. The Burley Tobacco Association operated during this period and it may have exerted some influence in stabilizing average market prices.

In the period from 1927 to 1929, a material increase in seasonal variation occurred. It was about this time that the ten-cent-cigarette companies were becoming important. The depression period following 1929 gave the low-price-cigarette manufacturers an opportunity to establish themselves and the amount of variation in the weekly prices continued to increase in the periods, 1930-1934 and 1935-1937. (Figure 4.) The ten-cent-cigarette companies may have exerted a greater influence on prices than their volume would indicate, because of their need to build up stocks of tobacco and because of the possibility of becoming strong competitors in the future.

The question may be raised as to why competition among manufacturers or groups of manufacturers would cause seasonal variations in prices. It has been pointed out that the general tendency in the seasonal movement has been for prices to rise for a few weeks and then decline thru the remainder of the season to levels much below the prices in the opening week. Would not the interest of competitors force some to shift their buying to that part of the season when prices are lowest and thus equalize competition thru-out the season? This question is suggested by the fact that certain manufacturers of cigarettes have advertised that one reason for their ability to sell at low prices is that they purchase desirable grades at the end of the season after other buyers had satisfied their needs.

The answer may lie in certain inherent characteristics of the auction system of marketing Burley tobacco. The operations of

the system of selling may create a seasonal variation in the amount or intensity of competition. The selling season is a relatively short one. The entire crop moves out of the farmers' hands into market channels in the space of 10 to 15 weeks. There is no continuous selling thruout the year as exists for many agricultural products. Each season the market system must go thru a cycle of opening the market and starting sales, selling the bulk of the crop, and gearing the market to a close. Competition in the market may go thru a somewhat similar cycle. Buyers must estimate the quantity and quality of production and the amount and quality of the carryover, and arrive at prices which they are willing to pay. They probably open with bids somewhat under their original estimates in order to take care of possible errors in judgment.

Knowledge gained in the first few days of trading gives individual buyers a chance to revise their prices in line with the market. Prices which are unnecessarily high may be lowered and others must be raised in order to secure purchases of tobacco. A buyer then is in a position to enter the market aggressively to secure the supplies he may need. Many buyers acting at the same time with the same intentions serve to intensify competition. These competitive conditions may account for the general rise that has occurred in prices during the first three or four weeks of many market seasons.

Several other factors may serve to intensify and increase the tempo of competition in buying, once opening prices are established. The fact that the main part of the crop is sold within the first five or six weeks of the marketing season may encourage some buyers to get their supplies during that period. This is especially true in the purchase of some types and grades of Burley tobacco. The quantity and quality available often are not clearly established until well in the marketing season. The buyer who waits until the latter part of the season for the purpose of taking advantage of possible low average prices may be unable to purchase a sufficient amount of the qualities which he desires. In some years prices for selected grades have advanced substantially rather than declining with the average for the market at the end of the season. The advantages of greater volume from which to select and more certainty of being able to obtain the type of

tobacco desired may be of sufficient importance to justify higher prices in the first part of the market season.

Another factor which may stimulate competition early in the season is the activity of tobacco dealers on the auction markets. Commission buyers receive orders to buy certain amounts of specific grades of tobacco and are interested in filling the order as soon as possible and with certainty. Such orders undoubtedly accumulate at the opening of the marketing season. Once the orders are filled, however, commission buyers may withdraw from the market and thus reduce competition and cause, in part, the declining prices at the last part of the season.

All these factors, and perhaps others, may have operated to create a seasonal increase and decrease in the tempo of competitive buying of Burley tobacco. If competition has tended to increase during the past thirty years, as suggested above, then the character of the auction system of selling probably has become gradually more influential in shaping the seasonal variation of competition in buying.

The increased demand for cigarettes during the last twenty or twenty-five years cannot be overlooked in explaining the seasonal movement of prices for Burley tobacco. The popularization of cigarette smoking during the first World War and the adoption of cigarette smoking by women in recent years has created an expanding market for Burley tobacco. The increased consumer demand for cigarettes, undoubtedly, has stimulated and encouraged manufacturers to seek a share of the enlarged retail market. It is difficult to say how much of the increase in competitive effort to secure a greater share of the retail market extends back to the auction floor in securing a greater share of the Burley produced, but it is probable that the seasonal character of market prices in recent years would have been quite different if the conditions had been those of a declining demand for cigarettes and a relatively large supply in relation to the need for Burley tobacco. The stimulating influence that an increasing consumer demand might have on the bidding for raw tobacco would have been lacking under these conditions. If growth in demand for cigarettes is not maintained, some important changes may occur in the seasonal character of prices on the Burley auction markets.

Effect of High Prices Early in the Season. In the belief that market prices are higher early in the season, Burley growers have employed extra help in stripping tobacco, rented trucks for its delivery, and sometimes have sorted out the best grades to sell first when it was not possible to deliver the whole crop at one time. In spite of earlier marketing, however, the high point of average prices has continued to come earlier in the season than the high point of sales in most years, and thus has encouraged still earlier marketing.

In figure 9 the location of both the peak of prices and the peak of sales is illustrated by five-year moving averages. In the upper part of the figure the dotted line indicates the week of season in which the highest prices occurred. The solid line indicates

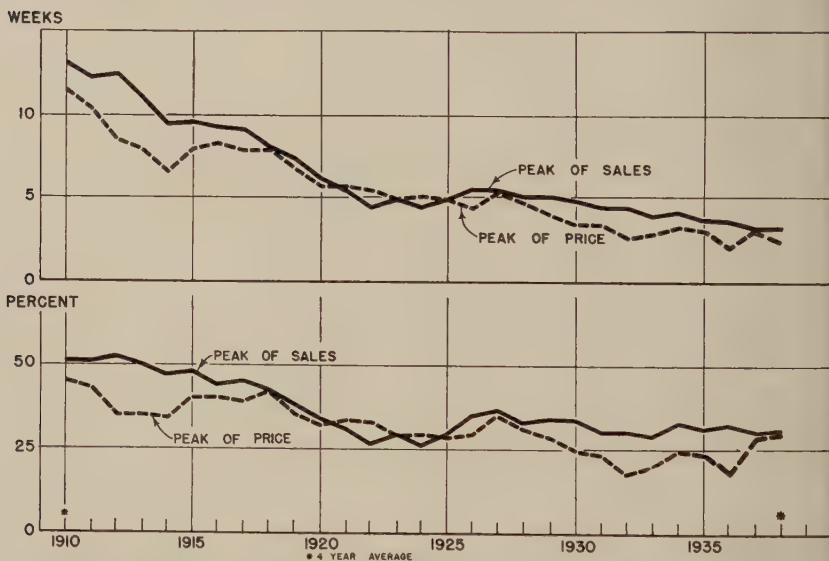


Figure 9. Five-year moving average of the number of weeks (upper) and the percent of season (lower) from the beginning of the season to the peak of sales and peak of prices on the Lexington Market, 1909-1937.

The highest average prices came ahead of the peak of sales except from 1921 to 1925 when a large share of the crop was marketed cooperatively.

the week of heaviest sales. In the lower part of the figure the same points are measured in percent of the total season, to allow for change in the length of selling periods. From 1910 to 1920 the high point in prices preceded the high point in sales

by one to four weeks. During the period, 1921-1925, when the Burley Tobacco Growers' Cooperative Marketing Association was handling a good share of the crop, prices tended to lag behind sales. After 1926, however, the peak in prices again came earlier, on the average, than the point of heaviest sales. The natural effect upon growers was a continual urge to market earlier in order to sell at the peak of prices.

In the years from 1909 to 1920, the peak of prices came when about forty percent of the marketing season had passed but the peak of sales did not come until nearly forty-seven percent of the market season had been completed. In 1921-1929 both peaks occurred when about thirty percent of the marketing season had passed. In 1930-1937, the peak week of prices came after approximately nineteen percent of the market season was over; but the peak of sales came after nearly thirty percent of the marketing season was completed, leaving eleven percent of the season between the two peaks. More recently the peaks have been closer together. Once established, the peak price itself may tend to become a self-generating force toward higher and earlier peaking of prices. The effort of farmers to take advantage of seasonal changes in price may operate, in turn, to enhance the early period of high prices. If the market declines ten percent, the loss sustained on high-priced grades means more dollars per pound than on low-price grades. Growers, therefore, are tending to market their better grades at the time when prices seem to be best. The effect of high prices at a particular time in the season, therefore, becomes cumulative.

Geographical differences also play a part in seasonal marketing. Regional differences in the quality of Burley tobacco and the tendency for deliveries to come from different areas during different parts of the marketing season may have more influence on the seasonal movement of average prices than the practice of farmers in selecting better grades for sale first. The introduction of large trucks in recent years, the earlier preparation for market and the practice of booking for certain sales may encourage the small farmers, particularly the distant ones, to deliver and sell their tobacco either early or late in the marketing season. Nearby farmers in the Bluegrass area have an advantage in getting their

crops on the warehouse floor at any particular time. They are in position to know more of the local conditions in the market and many have close connections with auction warehousemen. It is to be expected, therefore, that at the time when these growers think prices will be best, the market will be heavily supplied with tobacco from nearby farms. In general, tobacco produced in Central Kentucky is of better quality than that produced in other parts of the State. Since market prices are averages of all grades and qualities offered for sale, it may be seen that seasonal differences in the origin of tobacco may cause seasonal differences in market prices.

Table 15. Percentage distribution, by origin, of high-priced crops of Burley tobacco sold in Lexington during the 1937, 1938 and 1939 marketing seasons *

Source of tobacco	Week of season							
	1	2	3	4	5	6	7	8
	(Percent of total)							
Ten Central Kentucky counties ¹	67.8	82.3	81.8	81.5	79.5	70.5	48.2	50.0
Mountain area in Eastern Kentucky ²	11.4	2.1	1.0	.7	.6	.8	6.1	10.0
Other Kentucky counties	19.7	15.1	14.6	14.1	19.0	26.5	41.7	30.0
Other states	1.1	.5	2.6	3.7	.9	2.2	4.0	10.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Based upon 1644 crops in 1937, 5739 in 1938 and 749 in 1939, reported by Lexington newspapers because of the high average price for which they were sold.

¹ Bourbon, Clark, Fayette, Franklin, Garrard, Jessamine, Madison, Montgomery, Scott and Woodford counties.

² Twenty-six counties in Eastern Kentucky which compose Type of Farming Area I.

Few data are available on geographical differences in seasonal marketings but sales during the first week of the season frequently are heavily weighted with tobacco from Eastern and Southern Kentucky; while during the second, third, and fourth weeks of the season receipts from Central Kentucky are heavy. Lexington newspapers often list the names and addresses of growers whose crops bring good prices. While these crops may not represent a true cross section of the market the addresses suggest the area from which the tobacco comes. A tabulation of "high crops" listed during the 1937, 1938 and 1939 crop seasons suggests that proportionately more of the tobacco sold early in the season comes from outside of the Central Bluegrass area than during the height of the marketing season. (Table 15.) Altho this was

true in all three years it probably is a fairly recent development accompanying better roads and enlarged production of tobacco in areas outside of the Bluegrass. Geographical influence upon the seasonal movement of Burley tobacco prices, therefore, is classed as a long-time factor.

Change in Type of Tobacco Grown. A change in the type of Burley tobacco produced, to meet new market demands, also may favor earlier marketing. The heavier red type of Burley, grown extensively in the early part of the period under review, could be left in the barns longer without injury from weather conditions than the lighter type of Burley now so popular. The risk of loss thru depreciation of quality while hanging in the barns forces farmers to take down the Burley at the first opportunity and rush the stripping operations. The danger of loss from damage to quality is relatively small once the tobacco is properly bulked down. Other risks such as the danger of unfavorable changes in market prices, fire and theft force farmers to rush the tobacco to market once it is ready for sale.

SHORT-TIME FACTORS ASSOCIATED WITH SEASONAL MOVEMENTS

Aside from the underlying long-time factors which have been changing the seasonal movements of sales and prices of Burley tobacco, other conditions have influenced the patterns greatly in some years but only slightly or not at all in others. Such factors may emphasize or detract from the more gradual changes resulting from the long-time influences. The more intermittent influences are classed as short-time factors and include variations in weather, annual production, market information, average quality of the tobacco offered for sale, relative prices between grades, changes in price from the previous year, and legal restrictions on market movements. Seasonal variations in both sales and prices, by years, may be observed in figure 10.

Weather. Wind, humidity, temperature and rainfall affect the seasonal movement of sales. Their influence begins with the growing of the crop and does not end until the tobacco is redried and in the hogshead. The growing period is lengthened or shortened and the quality and amount produced are influenced by changes in weather conditions. Dry weather sometimes has retarded stripping and delayed preparation for market to such an

extent that the opening of the Burley market was delayed. In other years the weather was so favorable for curing and stripping that most of the crop was ready for delivery by the time the

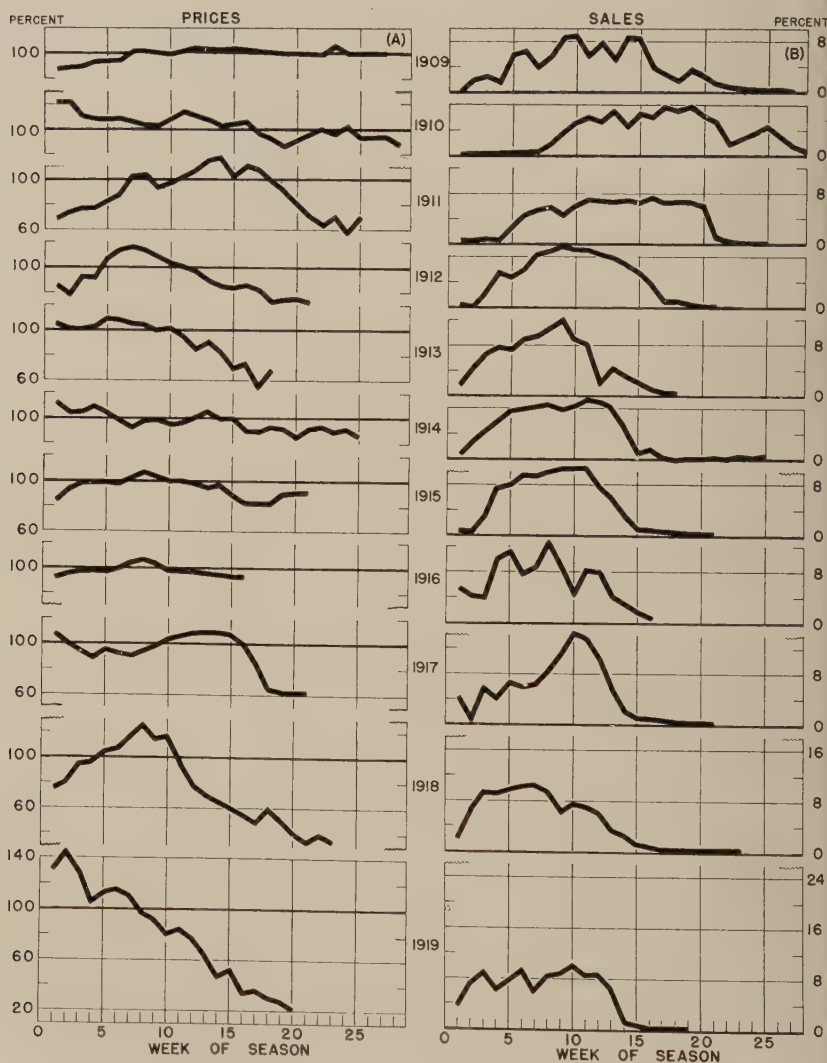


Figure 10. Weekly prices in percent of the season's weighted average price (left) and sales by weeks in percent of total sales for the season (right) on the Lexington Market, by years, 1909-1939.

market opened. The influence of this condition is illustrated in the 1932 season.

Cold weather influences the movement of tobacco from farms to auction floors and occasionally sales were stopped because of

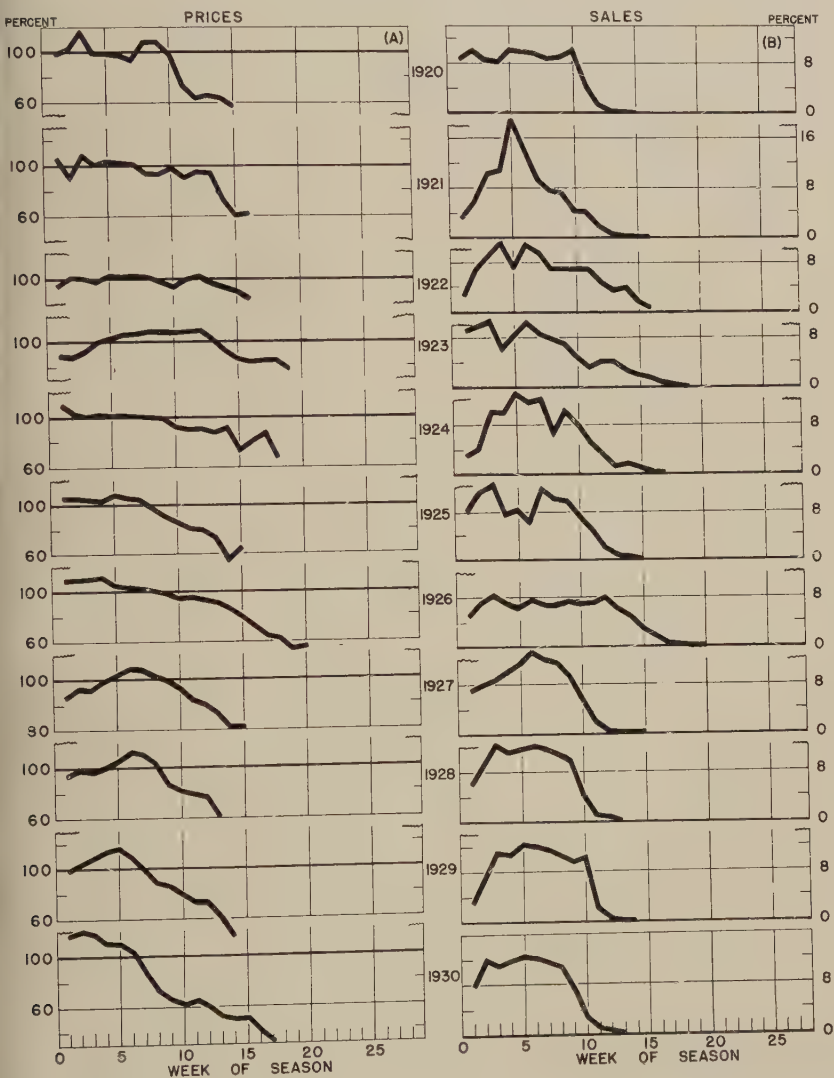


Figure 10 (Continued)

extremely cold weather, as in 1939. Several times during the early years, markets were closed temporarily for lack of tobacco. Farm-

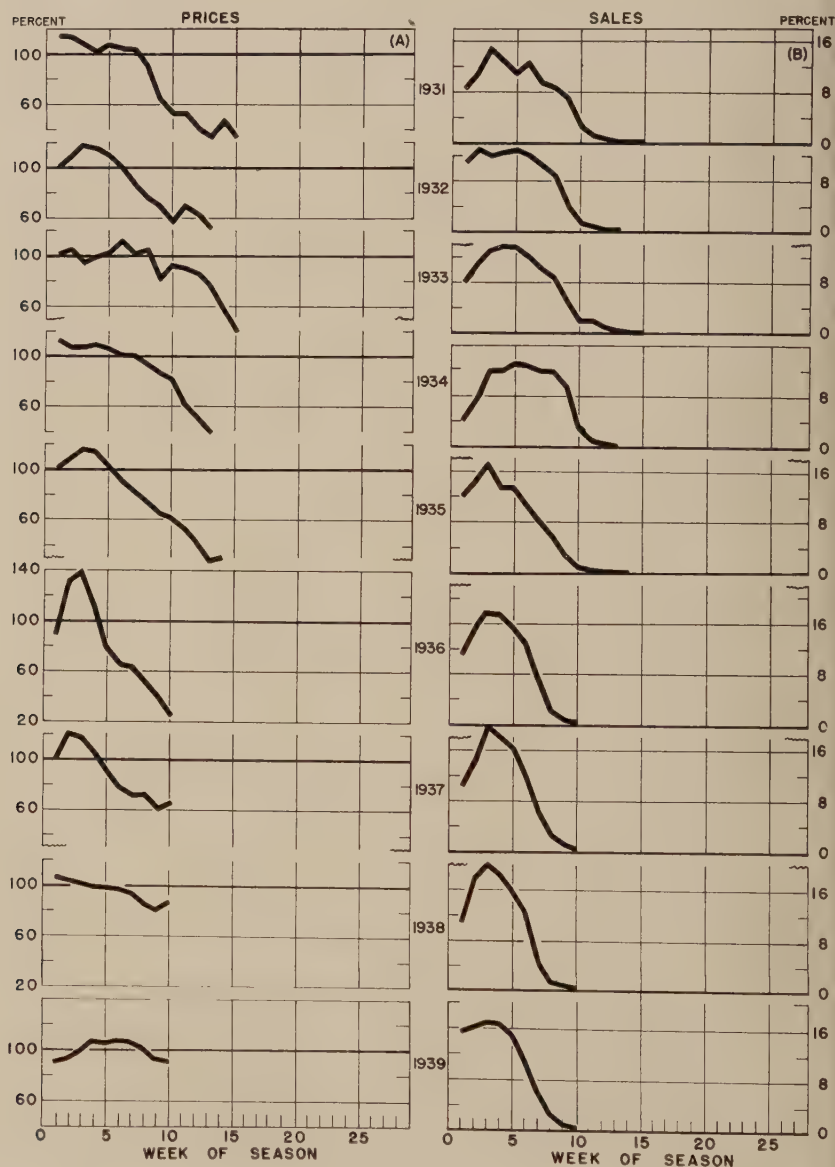


Figure 10 (Concluded)

ers delayed deliveries rather than expose their teams to the cold and run the risk of long waits in the market for the sale of their tobacco during cold weather. Sometimes muddy or icy roads have delayed deliveries, as in 1917. Extremely cold weather may retard stripping on the farms but lack of humidity is a more important factor in this respect.

Often during periods of rainy weather sales days must be shortened for lack of sufficient light. In some years snows have been so heavy that sales were delayed until the skylights could be cleared. Delays in sales for these reasons usually are short and do not extend beyond a day or two in length altho prolonged wet weather sometimes interferes with the rate of sales by slowing the operations of redrying plants. During part of the 1936 season the tobacco contained so much moisture that redrying plants were unable to receive and dispose of tobacco fast enough to clear the auction floors ahead of the sales.

Several changes in the production and marketing of Burley tobacco during the past 30 years have reduced the influence of weather upon the seasonal movement of sales. The use of stoves in stripping rooms has permitted more stripping during extremely cold weather. The substitution of trucks for teams and the construction of hard-surfaced roads permit greater stability in the rate of delivery to market under adverse weather conditions. Increased warehouse space, in proportion to the market's capacity to sell tobacco, also permits sales to proceed uniformly even with considerable fluctuation in the rate at which tobacco moves from the farms to the market. All these changes have contributed to smoothing out sharp but short irregular changes in the seasonal movement of sales. (Figure 10.) In the later years of the study the sale pattern has become not only smoother in appearance but more uniform in movement from year to year.

Annual Production. Production varies widely from year to year; so with no change in the market's capacity to handle the tobacco, the seasonal movement of sales during the season must vary. Large crops usually require longer selling seasons than small crops but the increased length often consists of a period of small sales at the end of the season. The volume of sales by weeks at the height of the season usually reaches a higher level in large-crop

years. This probably is due to greater production by individual farmers which permits making larger piles of tobacco on the warehouse floor and a greater volume of sales within a given time. Relatively large crops were produced in 1918, 1923, 1931, 1933, 1937 and 1939, while relatively small ones were grown in 1921, 1927, 1934, 1935 and 1936.

Market Information. Buying practices of tobacco manufacturers are based upon the estimated size of the crop which is moving to market, in relation to their prospective requirements. Errors in estimating the supply of tobacco available for sale, therefore, would be expected to result in decided changes in market prices when the errors are discovered. Most of the large manufacturing companies estimate the size of the crop at various times during the growing and curing seasons; and the United States Department of Agriculture, thru its crop-reporting service, makes public its estimates each month from July to December. Buying-company estimates are not made public but it is likely that these have more direct influence upon prices than do the government estimates.

In each year from 1931 to 1935, the estimate of Burley tobacco production made by the United States Department of Agriculture, as of December 1, was from 6 percent to 13 percent above the final revised estimate of production. In each of the years 1925, 1929, 1930 and 1937, it was from 7 to 13 percent below the final estimate. No significant differences in the seasonal movements of average prices in these years are apparent, however. (Figure 10.)

When prices by grades are considered, a tendency appears for prices of tobacco of the same grade to rise or remain relatively constant late in the season in years when the crop was overestimated and to decline in years when the crop was underestimated. In 1939, however, the December estimate was about 8 percent short of total production and prices by grades strengthened thruout the season. Private estimates are understood to have been extremely accurate in 1939. In 1936 the government estimate was accurate but private estimates are understood to have been too low. This may account in part for the rapid rise in prices of individual grades early in the 1936 season, but other unusual factors seem to have played a part in the extremely wide fluctuations of that year.

Quality. Average quality is an important factor influencing

the price of Burley tobacco from year to year. Inasmuch as the quality of tobacco sold on the Lexington market may vary during the marketing season because of different localities from which the tobacco comes, it seems probable that the variations in quality may cause differences in average prices from week to week. Scrap tobacco which has accumulated in warehouses sometimes is sold late in the marketing season and tends to lower both the average quality and the average price of tobacco sold at that time.

Data on quality, by weeks, have been compiled from two sources. During the seasons in which the 1930, 1931 and 1932 crops were marketed, a market news service was maintained in Lexington and quotations were broadcast by radio. In gathering the quotations, grade designations familiar to Burley growers were used. They recognized three qualities, "Good", "Medium" and "Common", in each major group of grades. The distribution of tobacco quoted by quality each week gives an indication of seasonal differences in the average quality of tobacco sold.

Figure 11 presents the proportion of tobacco graded as Good, and the average weekly price in percent of the season's average, by weeks, for the three seasons. The close relationship between price and quality is apparent. Correlation of the proportion of tobacco classed as Good each week with the price suggests that seasonal differences in price were due chiefly to differences in quality.¹ The measure of quality is not a refined one, however. Only three quality designations were used, whereas the United States Standard Grades for Burley tobacco recognize five quality classifications, and the Burley Association used seven in some years and eight in others. It is possible, therefore, that still further variations in quality took place within each of the three groups, Good, Medium and Common. In 1931 and from 1932 to date, the Tobacco Section of the U. S. Agricultural Marketing Service has maintained a grading and market news service on selected Burley markets. From information gathered in this way the proportion of tobacco sold in several quality groups, by weeks, has been estimated. These data apply to the several markets on which grading was done rather than to the Lexington market; so they are not

¹ The coefficients were: $r = +.97$ for 1930, $r = +.94$ for 1931, and $r = +.91$ for 1932, where r is the coefficient of correlation corrected for the small number of weeks in the marketing season.

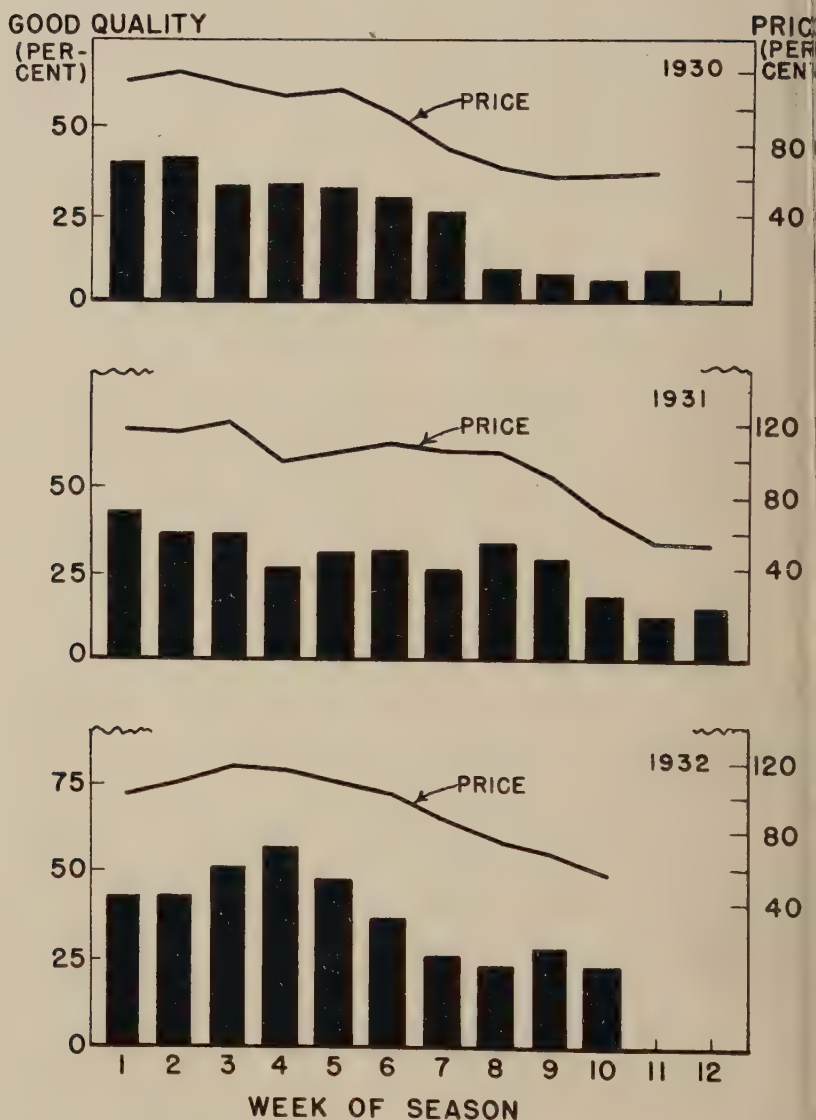


Figure 11. Price of Burley tobacco, in percent of the season's average price, and the percent of tobacco graded "Good," on the Lexington Market, by weeks, 1930, 1931 and 1932.

Seasonal differences in price are closely associated with the proportion of good tobacco offered for sale.

directly comparable with the seasonal prices already discussed. From prices by grades and the quantities graded, it is possible, however, to estimate weighted average prices for the markets where grading was done.¹

The proportion of tobacco falling in the three best out of five quality classifications is used as a measure of seasonal changes in quality. The relationship between quality measured in this way and the seasonal movement of average market prices is shown in table 16. It is apparent that relationship is not perfect.² This is partly because quality is not the only factor influencing the seasonal movement of prices and partly because of the inadequate measure of quality. The Federal system of Burley grades recognizes differences in color but the method used to measure quality does not. In the grades used for reporting the Lexington market from 1930 to 1932, a change in color was reflected as a change in quality. In the Federal grades, however, tobacco of different colors is put in different color groups but with the same quality designations. Failure to recognize this by using all the 1st, 2nd and 3rd qualities of the Federal grades may explain the poorer relationships between quality and price in most of the later years.

The importance of quality, as a factor in determining the seasonal movement of Burley prices, varies from year to year because of variations in the rate of marketing different qualities. This may be illustrated by comparing the Burley crops of 1931 and 1938.

The 1931 crop was one of low quality. The period of heavy rains during the late summer and fall damaged the crop and it contained a large proportion of the red and green grades for which demand was lacking. Marketings of these grades became heavier at the end of the season thus encouraged a rapid decline of the general market price even tho prices of individual grades strengthened.

Conditions in 1938, with respect to quality, were quite the reverse. The 1938 crop was one of high quality. Weekly prices on the Lexington market were exceptionally uniform thruout the season and varied from only six percent above the season's average price in the first week to 19 percent below at the last of the

¹ The number of baskets or the number of pounds of tobacco in each grade was ascertained thru the courtesy of Mr. Chas. E. Gage, Mr. J. V. Morrow and Mr. E. D. Booker of the Tobacco Section of the United States Agricultural Marketing Service.

² Coefficients of correlation are $r = +.81$ for 1931, $r = .00$ for 1933, $r = +.71$ for 1934, $r = +.91$ for 1935, $r = +.72$ for 1936, $r = +.95$ for 1937, and $r = +.90$ for 1938.

Table 16. Percent of Burley tobacco graded in the first three qualities and a seasonal index of average prices on selected markets, by weeks, 1933 to 1938 (Season's weighted average price=100)

Week of season	1933			1934			1935			1936			1937			1938		
	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	Price (Percent)	First 3 qualities (Percent)	Price (Percent)
1	46	92	40	114	105	72	105	81	48	19	107	33	113					
2	39	88	49	109	105	70	105	105	45	26	121	32	106					
3	39	101	46	105	115	67	115	120	41	28	124	27	97					
4	35	106	39	106	113	58	113	120	40	28	117	27	99					
5	29	102	38	94	112	68	112	92	37	24	100	28	98					
6	27	102	35	94	99	58	99	53	24	19	81	26	98					
7	24	96	35	99	92	57	92	48	18	17	74	24	95					
8	21	90	23	88	82	44	82			16	70	23	91					
9	21	91			73	44	73			13	59	25	*					
10					54	28	54			11	49	10	*					
Season	32	100	39	100	100	60	100		40	23	100	28	100					

* Prices by grades not quoted.

season. The quality of sales also was more uniform thruout the season than in other recent years. Many baskets of top-quality, light-colored Burley were seen on the floors in the last weeks of the season. The heavy sales of tips often occurring at the end of the market season were absent in 1938 and sales of these grades were light thruout the season. This probably was largely because the crop was of high quality with a high proportion of tobacco of smoking type, and some farmers threw away their low grades and tips because of marketing quotas or because the year before they had sold at a price which hardly paid for the cost of transportation.

Relative Prices Between Grades. The importance of seasonal variation in quality in affecting average prices is somewhat dependent upon the relative prices of the better and lower grades. When the spread between the prices of these grades is narrow, variations in quality have much less effect upon average market prices than when the range is large. In both 1938 and 1939 the spread between low-quality and high-quality grades was less than for several previous years. The relatively slight variation in market prices during these seasons doubtless was due in part to this condition.

Both the average quality of the crop being marketed and the quality of tobacco in storage influence the relationship between prices of different grades of tobacco. In 1938 and 1939, stocks of good quality tobacco were large and both crops contained a relatively large proportion of smoking grades. Data on the quality of tobacco in storage are not available for a sufficient number of years for adequate analysis; but the range between prices of low and high quality grades must influence the movements of general market prices to the extent that these grades vary in importance in the tobacco sold on the market.

Opening Prices. If the markets open at prices which are satisfactory to producers, sales progress normally and tobacco moves rapidly from farms to market. In some years, however, opening prices were so low that farmers expressed their disapproval by withholding tobacco and closing the markets. This happened in 1920 and 1933. Stripping and the preparation of tobacco for market continued during the period when the markets were closed,

however, so that sales at the reopening were normally heavy and apparently did not affect the seasonal movement of sales materially. The level of prices at which the markets open, therefore, has some effect upon the movement of tobacco to market; but within the usual range of prices it seems to be of minor importance.

Restriction of Production or Market Movements. Various forms of production, market or price restrictions have been employed from time to time which may have influenced the seasonal movement of tobacco to market or the average price at which it sold. Such efforts include the cooperative marketing experiment of 1921 to 1926, the marketing agreement of 1933, and various production allotment and marketing quota plans since 1934. The exact influence of these programs is not easy to measure.

From 1921 to 1926 the operation of the Burley Tobacco Growers Cooperative Marketing Association resulted in participating growers receiving the same price for like grades of tobacco regardless of when or where they were delivered to the Association. Only in the last year, 1926, was tobacco sold in loose-leaf form and at auction, so that prices and sales by weeks are available. Inasmuch as members received the average price for the season, there was no price incentive even then to deliver early or at any particular time in the season or for the better grades to move at one time and the lower grades at another. All grades moved to market at about the same rate thruout the season.

Figure 12 illustrates seasonal marketings by non-members and by the Association, in 1926. Sales thru Association warehouses were much slower than thru independent warehouses. In the first five weeks of the season non-members disposed of 32.2 percent of their tobacco while only 7.6 percent was sold for members during the same period. By the end of the 15th week non-members had sold 96.7 percent and members 80.7 percent of their total for the season.

Three causes account for the delayed sales by Association members: (1) the time required for the Association to change from its former method of receiving, grading and selling tobacco, to the auction method; (2) the lack of any price incentive to speed up deliveries by Association members; and (3) the necessity of transporting relatively large quantities of tobacco from receiving

points to points where sales were conducted. Of these the second is the only one which might be expected to influence sales under a permanently established system of cooperative marketing.

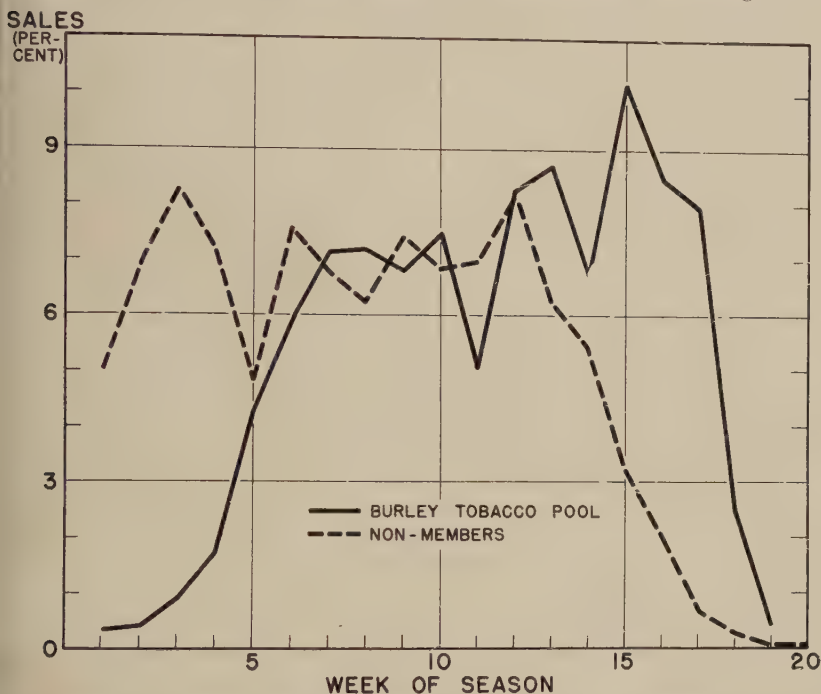


Figure 12. Weekly sales at auction by members of the Burley Tobacco Growers' Cooperative Marketing Association and by non-members, in percent of total sales by each group, on the Lexington Market, 1926.

Sales by members increased to a peak near the end of the marketing season but non-members sold tobacco at a relatively high rate during the first part of the season.

In 1933 a quite different type of price stability was tried. Low prices in 1931 and 1932 coupled with prospects for a large crop in 1933 stimulated plans for improving returns to growers. Under authority of the marketing agreement section of the Agricultural Adjustment Act, the Secretary of Agriculture entered into an agreement with the principal buyers of Burley tobacco under the terms of which the buyers agreed to purchase quantities equal to their requirements of the past year, at an average of 12 cents per pound. If purchases did not average 12 cents, buying companies were to turn over to the Secretary sufficient funds to bring their

average costs up to 12 cents per pound. This tended to stabilize prices until normal requirements were filled. Prices by grades held up thruout the season, (Figure 16) and average market prices fluctuated near the average for the season until the 9th week or until nearly 90 percent of the crop had been sold. (Figure 10.) The marketing agreement probably had little or no influence upon the rate at which tobacco was marketed.

In 1934, under the Agricultural Adjustment Administration, growers were issued marketing cards showing the amount of tobacco which they could sell without being subject to a heavy penalty. Tobacco over and above this amount was to be rendered unmerchantable and about 18,000,000 pounds of Burley is estimated to have been destroyed. Growers naturally withheld their lowest priced grades and brought them to market only in sufficient quantity to fulfill marketing allotments. Data available by grades indicate unusually small sales of low-grade tobacco in 1934, but the seasonal distribution of sales of these grades is not unusual.

During the early part of the 1935 marketing season, much the same conditions prevailed as in 1934, except that growers could purchase allotments for 3 cents per pound under which to sell excess tobacco. Marketing low grades again was discouraged until it became apparent, from a decision of the U. S. Supreme Court on January 6, 1936, that provisions limiting the sale of 1935-crop tobacco would not be enforced. Growers, therefore, were free to market all the tobacco grown. Marketings of low grades were heavy late in the season and average market prices declined steadily after the fourth week. The Supreme Court decision and fear of unrestricted production the following year probably had much to do with this decline.

The late marketing of low-grade tobaccos in 1935 is illustrated by the fact that at the end of the fifth week of selling only 47 percent of the tips, 35 percent of all low quality and 33 percent of all green-colored grades had been sold. These figures compare with about 60 percent of the flyings and lug groups, 70 percent or more of the choice and fine quality grades, and 65 percent of the light buff and tan-colored tobaccos. In years when production exceeds the poundage allotment, it may be assumed that

marketing quotas will result in reduced marketings of low-grade tobacco.

The 1936 and 1937 crops of Burley tobacco were sold without market restrictions but provisions of the Agricultural Conservation Program exercised some influence on production. In 1938, however, definite marketing quotas were again in force. Total production was somewhat less than the national quota set up for Burley tobacco so that sales by the rank and file of farmers were not affected by the quota. Quotas were transferable and in many cases this permitted growers with excess production to obtain marketing quotas from a neighbor whose production was below normal. Marketing quotas in 1938, therefore, probably had little direct effect upon the seasonal movement of either prices or sales that year.

Marketing quotas, which restrict the pounds of tobacco farmers are permitted to sell, logically may influence the seasonal movement of average market prices in three ways. By establishing an approximate maximum of tobacco to be sold during a marketing season they may contribute to an early adjustment between the factors of supply and demand in the market. They may result in much low-grade tobacco being eliminated from the market and hence practically limit the seasonal movement to that of high-grade tobacco thruout the season. In the third place, such marketing quotas may tend to postpone the marketing of low-grade tobaccos and thus emphasize the influence of seasonal differences in the quality of tobacco offered for sale. The importance of these effects will depend upon how closely marketing quotas and production coincide and upon unusual circumstances which occur during the marketing season such as the Supreme Court decision in January, 1936. The acreage quotas now in effect will influence the total amount of tobacco offered for sale but presumably will not limit the sale of low-grade tobacco or have any influence on seasonal movements to market.

Prices and Sales by Grades

Thus far the discussion has been centered around average market prices because they are most commonly used by growers of Burley tobacco and the public. As a matter of fact, however,

the income which each grower receives is the result of a series of prices for different grades of tobacco. The level of average market prices has been shown to be quite dependent upon the quantity of tobacco falling in different grades. It also is dependent upon the prices paid for these grades.

Analysis of seasonal variation of prices and sales by grades is limited to data furnished by the Federal Tobacco Grading Service. They apply only to the markets upon which grading was conducted and these, as a rule, are the smaller markets. The number of markets from which grade data were gathered varied from one in some years to 12 in 1938. The information, therefore, may not be strictly comparable from year to year, or with data already presented for the Lexington market. It is probable, however, that prices by grades do not vary materially between markets.

Federal Grading of Burley tobacco was made available for the first time in 1929, but data for that year are limited. No grading was done in 1930 or 1932 but this study goes back to 1931.¹ The period is too short to study adequately any historical shifts that may have occurred in the seasonal distribution of sales and prices for specific grades. The data available limit analysis to determining some of the more general characteristics of the seasonal movements in recent years and evaluating their importance.

The Federal Tobacco Grading Service for Burley tobacco provides for more than 65 separate grades based on the three general factors; group, quality, and color. The major group, which is the first factor, is a division of Burley including several closely related grades based on the general quality of the tobacco. There are four major groups, flyings, lugs, leaf, and tips, which have a general relationship to the position of the leaf on the plant. A fifth group, called nondescript, includes any tobacco which is nested, extremely dirty, or contains unusual amounts of foreign material, insects or wet tobacco.

Each of the major groups, except tips and nondescript, is broken into five qualities: choice, fine, medium, fair and common. Tips are divided into three qualities. Many factors, such as body of leaf, thickness, cleanliness, maturity, smoothness, and tensile

¹ The sample was rather small in certain years, particularly in some grades. Federal grading service quotes no prices where less than 20 sales occurred for a given grade. Interpolations were resorted to in some instances to complete the series of weekly prices.

strength enter into the classification of Burley tobacco on the basis of quality. Each quality is further classified by color. The colors used are light buff, tan, red, dark red, and green.

A number of factors make it difficult to analyze the movement of individual grades. First, there are a large number of grades to be considered and no one grade or small group of grades represents a very large proportion of the tobacco offered for sale. Second, the factors involved in grading are closely interrelated and sharp distinctions between grade factors are not possible. Analysis of one grade factor, therefore, cannot be distinguished entirely from others. In spite of these difficulties, however, seasonal variations in sales have been measured in terms of each grade factor and grades have been grouped into high grades, medium grades and low grades, for the analysis of seasonal movements of prices.

SEASONAL MOVEMENT OF SALES

In general, tobacco in the four major groups, flyings, lugs, leaf, and tips, moved to market at about the same rate. In 1935, the movement of tips was somewhat delayed because of unusual circumstances that year. Nondescript tobacco, which makes up two or three percent of the total, moved somewhat slower than the other groups. The seasonal movement of sales in 1937 is illustrated in figure 13 as a rather typical year.

Market movements are less uniform between quality and color classifications than between the major groups of grades. After the first week in 1937, the general tendency was for the better qualities of tobacco and the brighter-colored grades to be sold first and the poorer qualities and darker grades somewhat later. After the fifth or sixth week of the season sales of the lower grades were relatively more rapid. This seasonal movement corresponds to that presented for the years 1930, 1931 and 1932 in figure 11. By the end of the fifth week, in 1937, nearly 80 percent of the choice and fine quality tobacco had been sold but only 72 percent of the medium, 64 percent of the fair, and 56 percent of the common qualities. As to color, 73 percent of the light buff, 68 percent of the tan, 59 percent of the red, and 54 percent of the dark red Burley had been disposed of in the first five weeks of the season.

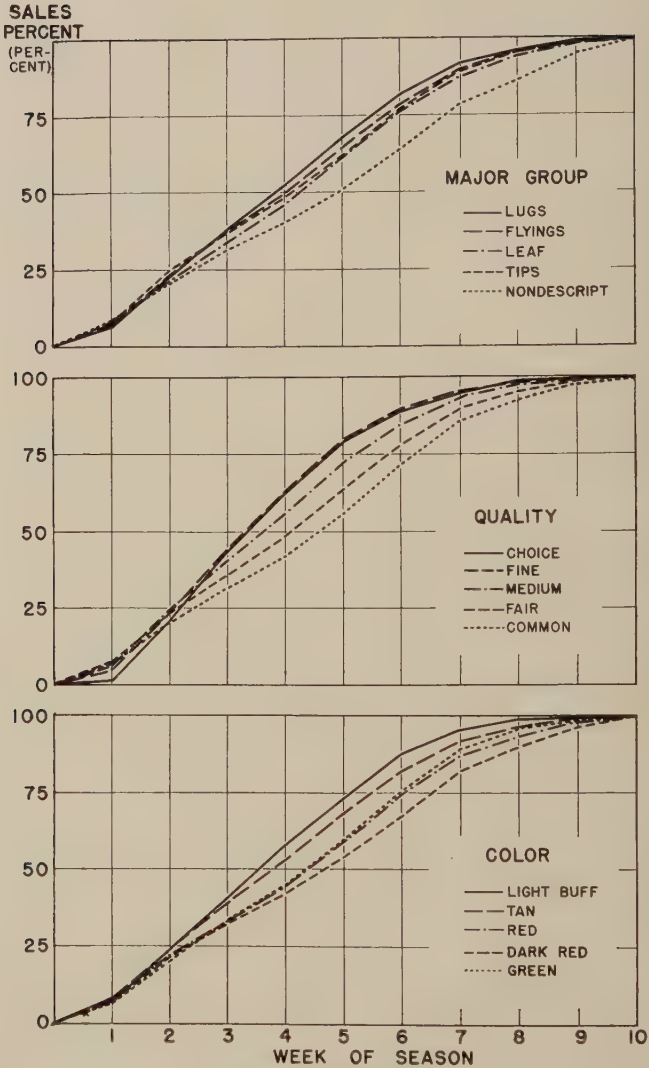


Figure 13. Cumulative weekly sales of Burley tobacco on five Kentucky markets, Danville, Mt. Sterling, Horse Cave, Cynthiana, and Bowling Green, in percent of total sales for the season by grade factors, 1937.

Tobacco of high quality and light color moves to market somewhat earlier than low-quality, dark-colored tobacco. Between the important major groups, however, the rates of marketing are quite uniform.

As pointed out earlier, seasonal differences in the quality of tobacco offered for sale are due in part to differences in the area from which the tobacco comes. Inasmuch as Federal grading, to quite an extent, was done on the smaller markets with less geographical differences in the territory served, it seems that seasonal changes on those markets must be due more largely to other factors such as the practice of better farmers selling at one time rather than another, or of individual farmers selecting their better grades to sell during the height of the season. The seasonal patterns of other years were in general the same as those in 1937.

The relative importance of grade factors in shaping the seasonal pattern of average market prices depends in part upon the distribution of tobacco between grades. In the seven years for which data were available the tobacco graded was composed of 19.8 percent flyings, 24.8 percent lugs, 41.3 percent leaf, and 14.1 percent tips, with the exclusion of the nondescript group. These proportions remained quite uniform from week to week thruout the marketing season. (Table 17 and figure 14.) The distribution of major groups, therefore, tended to stabilize the seasonal movement of average market prices.

Sales for the season were distributed as to quality about as follows: choice 1.1 percent, fine 6.2 percent, medium 25.5 percent, fair 46.6 percent, and common 20.6 percent. The distribution of quality, however, varied much more, both from year to year and from week to week, than that of the major groups of grades. On the average, the early weeks of the season had proportionately about twice as much choice and fine tobacco as the last weeks. Medium-grade tobacco decreased from 35 percent of the total to about 17 percent, but common grades were relatively about three times as important at the end of the season as at the beginning. Fair quality made up about 45 percent of the tobacco thruout the season. The relatively small amount of choice and fine tobacco gives those grades little weight in determining average market prices, but their high value per pound tends to offset somewhat the smaller quantity. The medium and common qualities have the greatest influence upon the seasonal movement of market prices. Taken together they make up about 45 percent of all tobacco graded each week but the ratio between them varies considerably. (Table 17.)

On the average, the quantity of medium grades sold early in the season was about three times that of the common grades, but late in the season the quantity of common tobacco exceeded that of medium.

Table 17. Percentage distribution of Burley tobacco, on markets with Federal grading, by major groups, quality, and color, 1931 to 1938 average, by weeks*

Grade	Week of season										Annual
factor	1	2	3	4	5	6	7	8	9	10	
Major Group											
Flyings	20.3	20.3	19.9	20.3	21.1	20.0	20.0	19.2	18.4	18.8	19.8
Lugs	26.3	26.2	28.5	27.7	24.8	23.9	23.6	22.0	22.0	23.2	24.8
Leaf	40.5	40.5	38.2	38.6	40.0	41.8	43.0	43.8	44.4	41.5	41.3
Tips	12.9	13.0	13.4	13.4	14.1	14.3	13.4	15.0	15.2	16.5	14.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Quality											
Choice	1.4	1.4	2.1	1.1	1.1	1.2	.9	.8	.7	.5	1.1
Fine	9.0	8.1	7.8	6.6	6.8	6.4	4.6	4.3	4.1	3.8	6.2
Medium	35.2	33.1	31.2	28.2	27.2	23.8	21.9	20.3	17.2	16.8	25.5
Fair	43.4	44.6	44.4	47.2	48.6	49.0	49.3	48.8	45.4	45.5	46.6
Common	11.0	12.8	14.5	16.9	16.3	19.6	23.3	25.8	32.6	33.4	20.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Color											
Light buff	5.2	4.9	5.7	5.8	4.6	4.0	3.5	2.8	3.2	3.5	4.3
Tan	61.6	56.8	57.6	55.7	54.9	50.6	48.6	46.2	39.2	38.8	51.0
Red	26.7	30.1	28.5	28.9	30.1	32.3	32.9	36.3	38.2	36.9	32.1
Dark Red	1.5	1.9	2.2	2.5	2.8	3.7	3.7	4.4	5.2	6.5	3.5
Green	5.0	6.3	6.0	7.1	7.6	9.4	11.3	10.3	14.2	14.3	9.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*1932 omitted for lack of data.

Color is closely associated with quality in the seasonal distribution of sales. Low-quality Burley usually is dark in color. Sales during the seven years averaged about 4.3 percent light buff, 51.0 percent tan, 32.1 percent red, 3.5 percent dark red, and 9.1 percent green. The light-buff Burley which is marketed more rapidly than any other color, has relatively little weight therefore, in the establishment of average prices. Burley tobacco of dark red color is still less important as a factor in determining market prices because of small quantity and low price. Less than two percent of the total sales during the first week were dark red but



Figure 14. Percentage distribution by major groups, quality, and color, of Burley tobacco sold under Federal inspection, by weeks, 1931-1938 average. (1932 omitted for lack of data).

The distribution between major groups was quite uniform thruout the season. Tobacco of fine and medium qualities and tan color was relatively more important in the early weeks and less important in the later weeks of the season while common quality and dark color were relatively more important late in the marketing season

at the end of the season, over 6 percent of all sales were of this color.

Changes in average market prices attributable to difference in color were due very largely to a decline in the proportion of tobacco of tan color and an increase in the proportion of red-colored tobacco. Tan Burley declined from 62 percent in the opening week to 39 percent in the closing week. Red Burley increased from 27 percent in the first week to 37 percent of total sales in the tenth week of the season. Sales of green Burley increased from 5 percent in the first week to about 14 percent in the last week of the season.

SEASONAL MOVEMENT OF PRICES

An analysis of prices by grades revealed that seasonal movements were associated more closely with quality and color than with major groups of grades. Seasonal movements differed considerably between grades but there was little or no tendency for grades within the major groups to move together. In general, prices of the top grades in color and quality showed the greatest stability. Greater percentage variation and greater irregularity in seasonal movements of prices existed for those grades having the lowest quality and darkest color. (Figure 15.)

For purpose of analysis the grades were divided into three groups based largely on quality and color. The first group includes the higher qualities and brighter colors of flyings and lugs; the second, the fair and common qualities of bright flyings and lugs and the fine and medium qualities of the red-leaf grades; the third, the darker colors and lower qualities of flyings, lugs, leaf, and tips. The distribution of sales and the movement of prices in each group are presented in figure 16. A greater stability in the prices of the higher grades, compared with the lower grades, is apparent in each year.

Except for the years 1931 and 1936, very little seasonal variation occurred in the prices of light buff and tan, fine and choice lugs and flyings. During the seven years for which data were available, the average variation in weekly prices for the grades included in the high-grade group amounted to only a little over

6 percent of the annual price. (Table 18.) The average variation of prices in the low-grade group was nearly 14 percent. The highest weekly price of the better-grade tobacco was 108 percent of the annual average price, with a range between the highest and lowest

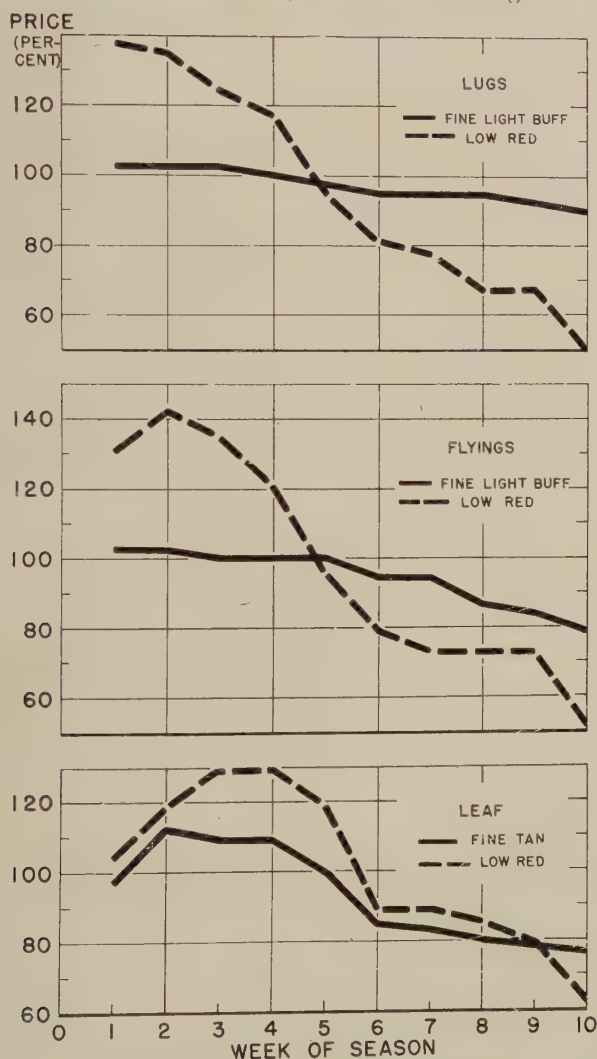


Figure 15. Weekly prices, in percent of the seasons' average price, for selected grades of Burley tobacco sold on five Kentucky markets, 1937.

Fine-quality lugs, flyings and leaf showed less seasonal fluctuation in price than low quality red tobacco in those groups.

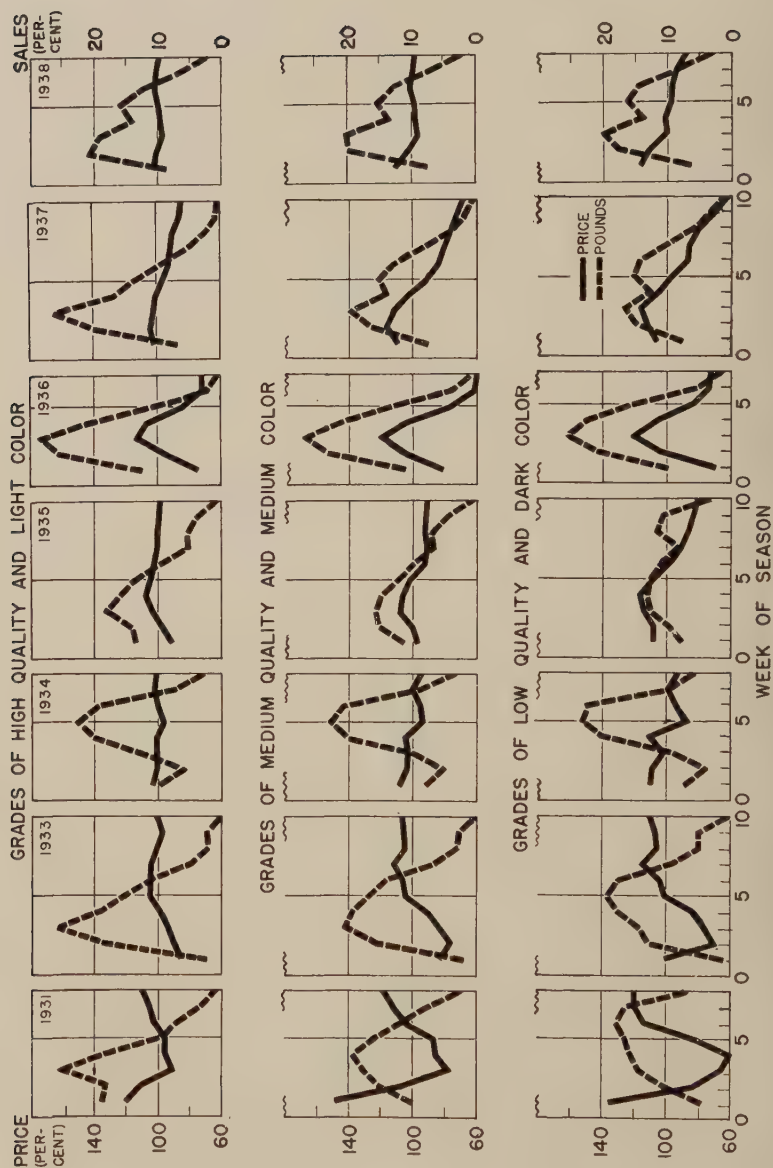


Figure 16. Weekly prices in percent of the season's average price, and weekly sales in percent of total sales for the season, by groups of grades, on Burley markets having Federal grading service, 1931-1938. (For grades included in each group see footnote to Table 18. Year 1932 omitted for lack of data.)

Prices of high-grade tobacco are much more stable throughout the season than are prices of low-grade tobacco.

prices of 20 percent. For the lower grades the range in prices was 46 percent of the annual price.

Table 18. Seasonal variation of weekly prices, in percent of the season's average price, by groups of grades on Burley markets with Federal grading service, 1931 to 1938 *

Grade group ¹	Average deviation of weekly prices	Week of highest price	Week of lowest price	Range in weekly prices
	(Percent)	(Percent)	(Percent)	(Percent)
High grades	6.1	108	88	20
Medium grades	11.2	117	80	37
Low grades	13.7	120	74	46

* 1932 omitted for lack of data.

¹ The grouping of Federal grades for determining the seasonal character of Burley grade prices is as follows:

High-grade group: C1L, C2L, C3L, C1F, C2F, C3F, X1L, X2L, X3L, X1F, X2F, X3F, and B1F.

Medium-grade group: C4L, C5L, C4F, C5F, C3R, C3G, X4L, X5L, X4F, X5F, X3R, X3G, B2F, B3F, B1R, B2R, B3R, B3D, B3C, and T3F.

Low-grade group: C4R, C5R, C4G, C5G, B4F, B4R, T4F, T5F, T3R, T4R, T3D, T3G, X4R, X5R, X4G, X5G, B5R, B4D, B4G, T5R, T4D, T5D, T4G, T5G.

The importance of these variations in affecting returns to growers depends upon both the amount of tobacco in each group and the level of grade prices. Using 1937 as a fairly typical year it was found that the upper group of grades represented 11 percent of the tobacco and sold for a weighted average price of 34.6 cents per pound. Grades in the middle group made up 35 percent of the tobacco and averaged 24.5 cents per pound, but the lower grades made up 54 percent of all tobacco and averaged only 11.3 cents per pound. At these prices the three groups made up 21 percent, 46 percent and 33 percent, respectively, of the total value of the tobacco graded in 1937.

Figures given in table 18 indicate that the range in price during the 1937 season, in cents per pound, was 6.9 cents ($34.6 \times 20\%$) for the better grades, 9.1 cents ($24.5 \times 37\%$) for the medium grades, and 5.2 cents ($11.3 \times 46\%$) for the lower-grade tobaccos. As is to be expected, seasonal variation in cents per pound, or dollars per hundred pounds, is somewhat less for the low-priced tobacco even tho the percentage variation is greater. The difference, however, is not sufficient to offset the greater quantity of tobacco falling in the lower grades. Variation in the prices of either the medium or low-quality groups of grades appears to be three

to four times as important as in the high-quality group in affecting the income which a grower may expect to receive from his crop when sold at different times in the season.

In selecting the best time of the season to sell tobacco a grower has more to gain per pound from the better and medium quality grades but his total income is influenced more by selecting the right time to sell the low and medium grades of tobacco. In most years under review, however, the prices of all three groups of grades were at their best at about the same time. (Figure 16.)

Farmers probably have been the least successful in selling the low grades at the season's highest price. It has been pointed out elsewhere that the low grades move to market more heavily late in the season. In 1931 and 1933, this practice probably was to the farmers' advantage because the trend of prices was materially upward during most of the season. (Figure 16.) In other years for which data were available, the practice of leaving the lower grades for late delivery probably lowered the farmers' possible returns because the price trends were downward thru most of the season.

Other factors than the seasonal trend in prices, however, must be considered in seeking the greatest possible return from the tobacco enterprise. There is the risk of depreciation in quality and color which is greater in the case of high-grade tobacco of thin body. The reduction in price as a result of damage to the quality and color of tobacco may do more to lower the total receipts than errors in selecting the time to sell for the highest possible price. Risks of fire and theft also are important. The greater value per pound of the higher grades may justify giving them first consideration in the reduction or elimination of these risks.

Separate Effects of Quality and Price. Inasmuch as the average market price of Burley tobacco is influenced from week to week by both the prices paid for individual grades and the proportion of tobacco falling in those grades, an effort was made to segregate and measure the influence of each factor. Data furnished by the Tobacco Market News Service were used for this purpose.

Average prices on the markets where grading was done were not obtained weekly so it was necessary to calculate such prices from the quantities of tobacco graded and the prices quoted. Prices so calculated, by weeks, reflect the combined effect of changes in

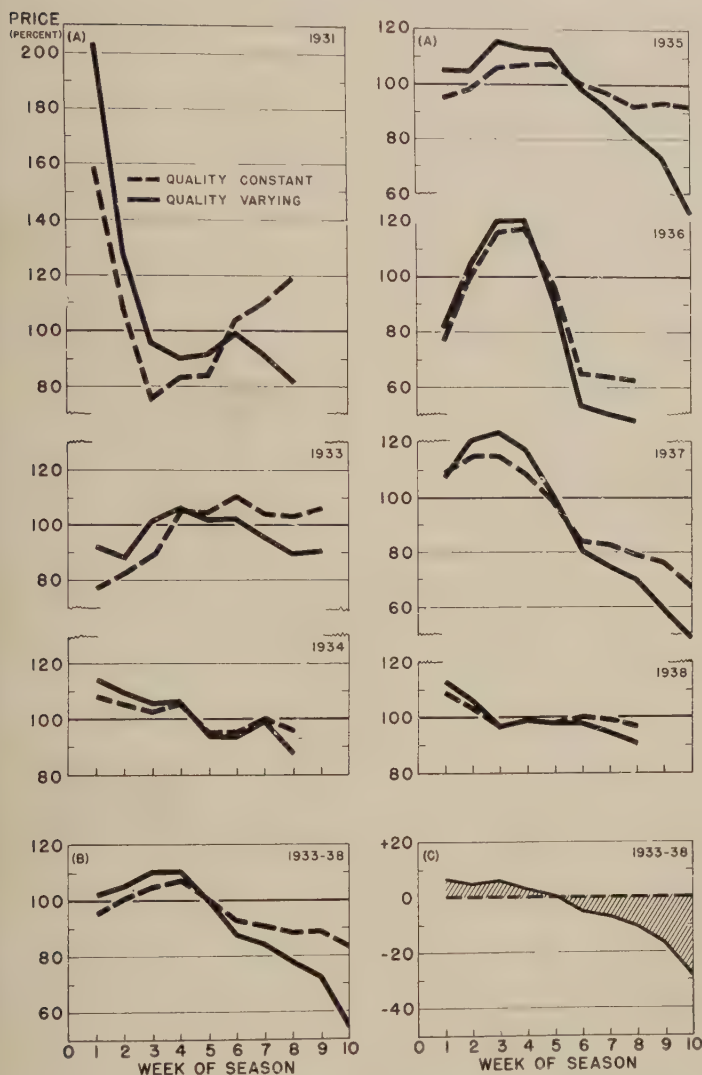


Figure 17. (A) Average prices of Burley tobacco with quality varying from week to week and with quality held relatively constant during the marketing season, 1931 and 1933 to 1938; (B) the six-year average, 1933-1938; and (C) the average difference in price due primarily to seasonal variation in the quality of tobacco, all expressed in percent of the season's average price.

Average market prices varied considerably during the season but a large part of the variation was due to seasonal differences in the quality of tobacco offered for sale.

prices by grades and changes in the distribution of tobacco among various grades. By maintaining the distribution among grades constant from week to week but using the current price quotation it was possible to approximate the average price which would have prevailed if the quality of tobacco offered for sale had remained constant. The distribution of tobacco by grades for the entire season was used as the constant weight.

Indexes of weekly prices calculated from the fixed annual weights and from the variable weekly weights are shown in figure 17. The solid lines represent the approximate average market price for all grades of tobacco sold, by weeks, each year. The broken lines indicate roughly the seasonal movement of prices of Burley tobacco of given grade and quality. Both series are expressed in percent of the season's weighted average price. The difference between the two lines is largely attributable to differences in quality. The dotted lines represent price returns to the average producer of Burley tobacco at various times during the marketing season. They show how average market prices would have varied had the quality of tobacco sold remained constant.¹

Apparently, seasonal variation in the quality of tobacco sold has a much greater influence upon average market prices in some years than in others. In 1933, grade prices rose sufficiently to practically offset the influence of progressively poorer quality and average market prices remained relatively stable. In 1936, the effect of variations in quality was small compared with the wide fluctuation in average market prices. Data for 1931 are considered less adequate than for most of the other years.

An average for the years 1933 to 1938, inclusive, suggests that during most of the first four weeks of the season, both series of prices were above 100 percent of the season's average price while during the last five weeks they were below 100. The weekly market average price, however, showed considerably greater seasonal variation than did prices by grades. The average market prices varied from 56 percent of the season's price to 110 percent, but

¹ The accuracy of Federal grades in measuring the quality of tobacco may be questioned. In each grade there is a range of quality which permits some variation. In one part of the season a large portion of the tobacco in a given grade may be near the top of the grade while at another the bulk of tobacco may fall near the low side. Such differences are not reflected by a distribution between grades. Figure 17, therefore, tends to minimize the influence of quality upon price and to maximize actual changes in market prices.

prices for tobacco of relatively constant quality varied only from 84 to 107 percent of the season's average.

The lower right-hand part of figure 17 illustrates the character of influence which quality has exerted upon average market prices in recent years. During the first week of the season, market prices were about 6 percent higher than they would have been had quality remained constant thruout the season. In the last week they were about 28 percent lower than they would have been with constant quality. The marked effect of poor-quality tobacco on the market late in the season is apparent. Lack of data makes it impossible to determine whether seasonal variation in quality has had an important influence upon weekly prices thruout the period of loose-leaf auction selling or if it is a matter of comparatively recent origin. It is highly probable, however, that historical developments in the industry have permitted the quality of tobacco offered for sale to have an increasing effect upon seasonal prices of Burley tobacco.

Seasonal Movements in Other Markets Than Lexington

From lack of data it was necessary to confine the discussion of seasonal variations in prices and sales almost entirely to the Lexington market and to a few markets with Federal grading. Data from the Carrollton market indicate that seasonal movements in that market were similar to those in Lexington for a number of years but data were not available from other markets.

Inasmuch as Lexington is the largest Burley market and is located in the heart of the heaviest-producing area, it may be questioned whether seasonal movements are the same as in smaller markets or in markets located elsewhere. As a result of information gathered by the Agricultural Adjustment Administration it is possible to compare the seasonal movement of average prices and sales on all markets for Burley tobacco during the 1935 crop marketing season.

SIZE OF MARKET

The sales season was slightly shorter in the small markets than in the larger ones, in 1935, and sales, in proportion to the total volume, were relatively heavier early in the season. (Table 19 and figure 18.) About 90 percent of the tobacco was sold by the end of

the fifth week, on the smaller markets, while only 80 percent had been sold in markets of over 6,000,000 pounds in size, and a little over 70 percent in Lexington. This suggests that the season's volume of sales is somewhat less in proportion to actual sale capacity on the smaller markets. In Lexington, for example, each set of buyers bought over 15,000,000 pounds of tobacco that year but only three of the other 40 markets handled a total of 10,000,000 pounds or more.

Table 19. Relation of size of market to the seasonal movement of sales on 41 Burley markets, 1935

Volume of sales per market		Number of markets	Average length of season	Percent of total sales	
Range	Average			Week of heaviest sales	First five weeks of season
(Pounds)	(Pounds)		Weeks	(Percent)	(Percent)
Less than 1,500,000	930,923	8	8.6	28.9	90.3
1,500,001-3,000,000	2,285,878	8	8.8	25.2	89.1
3,000,001-4,500,000	3,497,290	9	10.0	20.6	83.2
4,500,001-6,000,000	5,297,916	8	9.8	19.8	82.4
6,000,001 and over	9,577,965	7	9.9	19.7	80.2
Lexington	50,569,923*	1	14.0	17.8	71.1

* This figure differs from that given in Table 22 because it does not include resales and was compiled from different reports.

The movements of prices were similar in small and large markets. Altho relatively somewhat lower late in the season, prices on the small markets actually held up better than in Lexington when related to the volume of sales. In 1935, at least, average market prices were more stable thruout the marketing season on the smaller markets. (Figure 18.) This may be due to greater uniformity in the quality of tobacco offered for sale from the smaller areas served by these markets but data are not available to verify such a conclusion.

GEOGRAPHICAL LOCATION

To measure possible differences in seasonal movements due to geographical location of markets, the Burley district was divided into six areas based somewhat upon differences in the tobacco produced and upon the natural grouping of the markets. (Figure 19.)

The seasonal distribution of sales was similar in most of the market areas even tho the selling season was shorter than in Lexington in all areas except Western Kentucky. In Eastern and Middle

Tennessee sales were relatively heavier early in the marketing season and in Missouri they were slightly heavier in the fifth and sixth weeks. (Figure 20.) A number of small markets are located in Middle Tennessee which may account for the distribution in that area. Average production per farm is low and preparation for market can be completed early in the season. A long market-

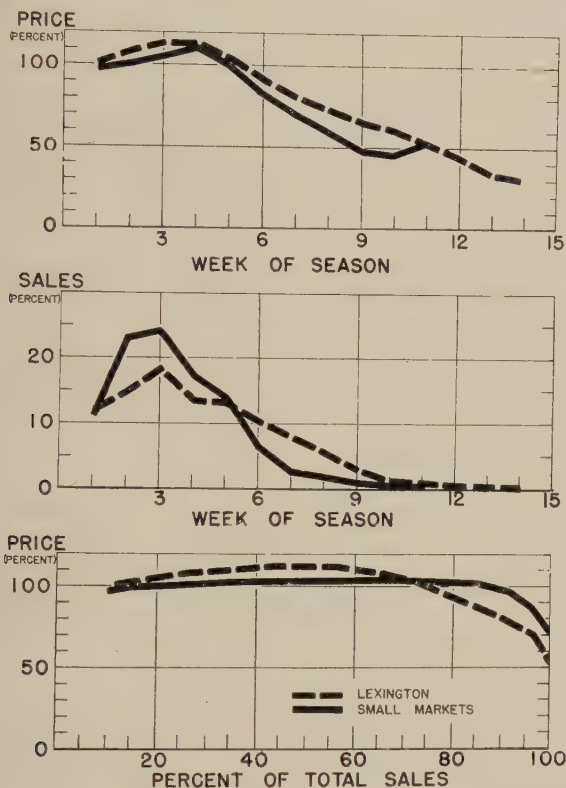


Figure 18. Sales of Burley tobacco, by weeks, in percent of total sales, and prices in percent of the season's weighted average price, by weeks and by accumulated percentage of total sales, on the Lexington market and on 5 small tobacco markets, in 1935.

Prices were strikingly similar in Lexington and the smaller markets even tho sales were relatively heavier early in the season on the small markets.

ing season in Western Kentucky doubtless is due to the long marketing season for dark tobacco in that area. In general, however, the seasonal distribution of sales on the Lexington market is rep-

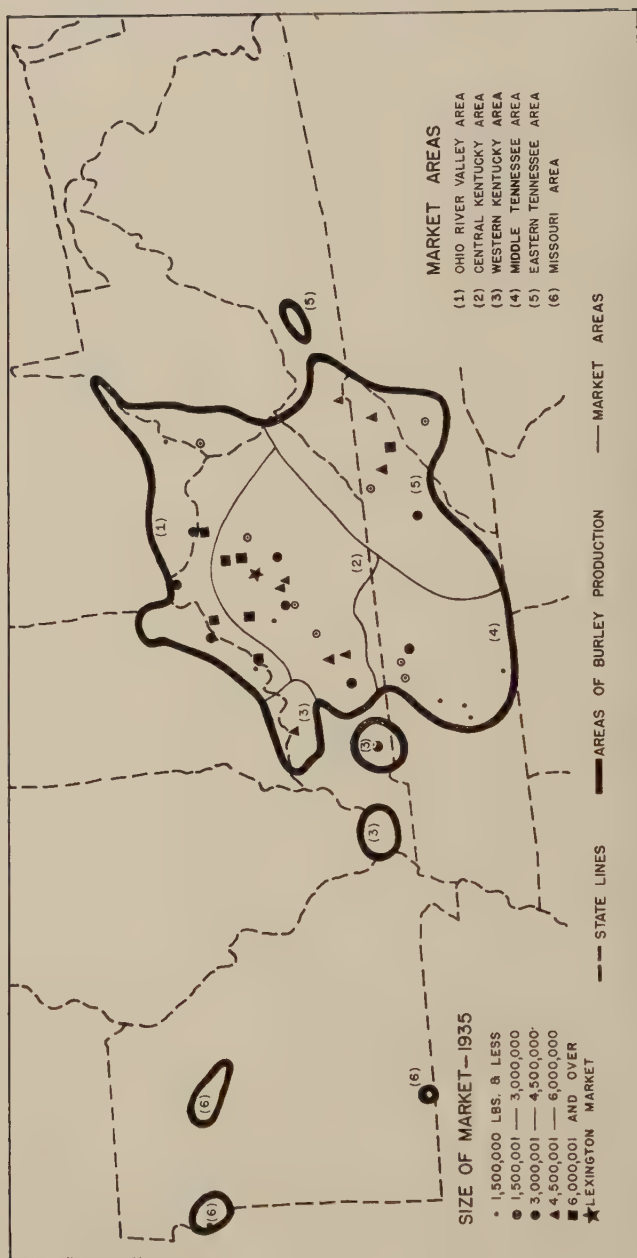


Figure 19. Size and location of Burley tobacco markets and market areas.

representative of other areas altho in 1935 both the early-season rise and the late-season decline in sales were more gradual in Lexington than in other markets.

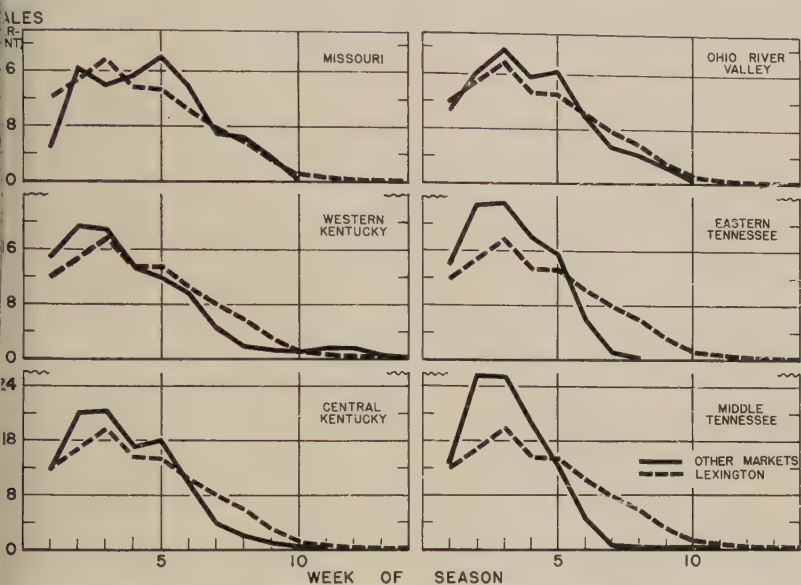


Figure 20. Sales of Burley tobacco, by weeks, in percent of total sales for the season, on the Lexington market and on 40 other markets, grouped by market areas, 1935.

The distribution of sales was similar in all areas except Eastern and Middle Tennessee where sales were relatively heavier early in the season.

The seasonal movements of prices were even more uniform between market areas than those of sales, particularly when viewed in relation to the accumulated volume of sales. (Figure 21.) Here again it is the Middle and Eastern Tennessee markets which appear to differ most from the movements in Lexington. Both the high point in prices and the late-season price decline came earlier in Lexington, in relation to the volume of sales, than in the Tennessee markets.

The extent of variation in weekly prices is greater on the Lexington market than in other markets of the district, due chiefly to the extended decline in prices after other markets have closed. The slight importance of this period, however, is indicated at the right of figure 21, where prices are related to accumulated sales. Here the decline in Lexington is no greater than in other markets

except those in the Tennessee areas. Earlier marketing in these areas may account for the difference.

Table 20. Number of Burley tobacco markets, sales per market, and similarity of seasonal movement in average prices, by market areas, 1935

Area	Number of markets	Average sales per market	Weekly prices changing in same direction as Lexington prices		Seasons weighted average price per 100 lbs.
			First 10 wks. of season	Entire season	
		(Pounds)	(Percent)	(Percent)	(Dollars)
Missouri	1	1,462,966	78	78	12.21
Western Kentucky	2	3,858,528	72	64	16.90
Central Kentucky	14	4,908,198	85	84	18.51
Ohio Valley	9	4,738,268	88	88	17.68
Eastern Tennessee	7	4,903,674	74	74	21.54
Middle Tennessee	7	1,682,026	70	68	19.81
Lexington market	1	50,569,923*	100	100	20.03*
All markets	41	217,491,173	81	79	19.19

*This figure differs from that given in Table 22 because it does not include resales and was compiled from different reports.

Table 21. Number and percent of Burley markets with average prices changing from week to week in the same direction as prices in Lexington, 1935 marketing season

Week of season	All markets	Prices moving with Lexington prices	
	(Number)	(Markets)	(Percent)
1	—	—	—
2	40	32	80
3	40	32	80
4	40	13	32
5	40	37	92
6	40	40	100
7	38	36	95
8	36	29	81
9	27	24	89
10	23	18	78
11	7	2	29
12	2	1	50
13	2	1	50
14	1	0	0
Total	336	265	79

On the average, price movements up or down on the Lexington market were accompanied by movements in the same direction on other Burley markets about 80 percent of the time. (Tables 20 and 21.) The similarity of movement was most pronounced near the middle of the marketing season, while the greatest variation occurred near the end of the season. At this time small markets were nearly ready to close while some of the larger markets still were handling a fairly large volume of business. It may be concluded, therefore, that seasonal movements on the Lexington mar-

ket are quite representative of all markets in the Burley-growing district.

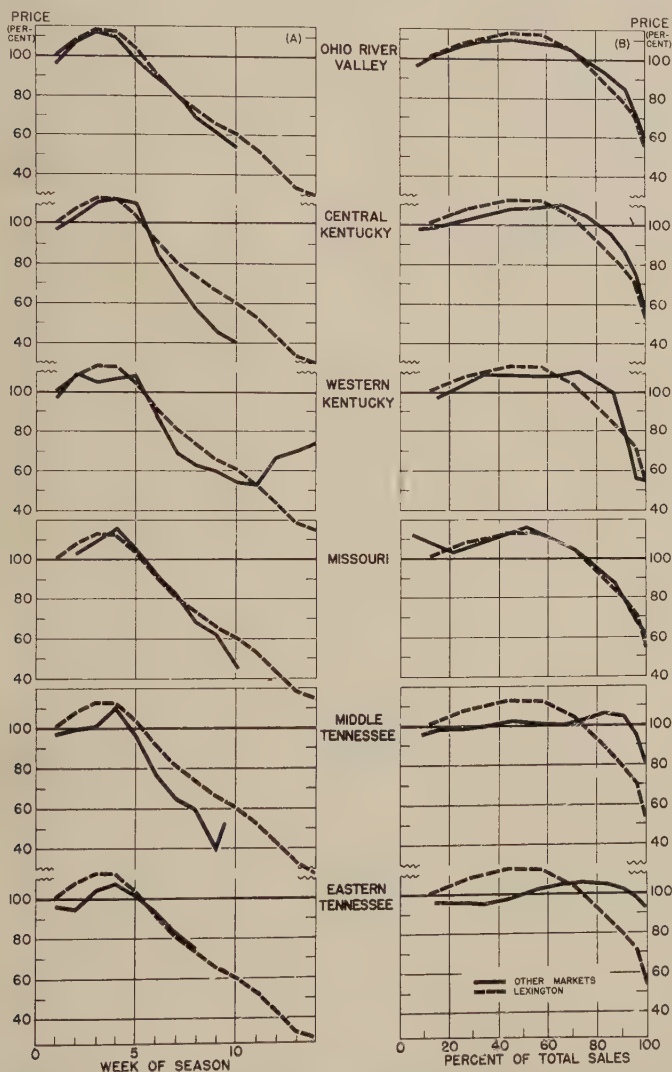


Figure 21. Prices of Burley tobacco, in percent of the season's average price, by weeks (left), and by accumulated percentage of total sales (right), on the Lexington market and on 40 other markets, grouped by market areas, 1935.

The seasonal movement of market prices was strikingly similar in all areas, especially when related to volume of sales. The movement of prices in Eastern and Middle Tennessee varied somewhat from that in Lexington, however.

Summary

The marketing season for Burley tobacco has become progressively shorter during the past thirty years and now usually is about two-fifths of its former length. The markets open three or four weeks later than formerly but close eight or ten weeks earlier, making a shorter sales period starting early in December and closing in late February or in March, depending somewhat upon the size of the crop.

The production of Burley tobacco has increased from about 225 million pounds per year to about 315 million pounds, and sales on the Lexington market have doubled, since 1909. The increased volume of business during a much shorter selling season has been possible only thru the expansion of market facilities increasing the speed of sales and the number of sets of buyers operating on the market. It is probable that the average weight of tobacco per basket also has been increased. The market's ability to receive, handle and sell tobacco has increased more rapidly than the total volume of sales, especially since 1926.

In spite of a shorter selling season in recent years sales have been shifted forward until 40 percent of the tobacco now is sold in the first quarter of the marketing season. Unlike many farm products the period of heaviest sales during the marketing season usually is the period of highest average prices. The peak of sales and the peak of prices frequently almost coincide. The general tendency is for average prices to rise for a few weeks and then decline during the rest of the season. Seasonal variation in prices increased until 1937 but during the past two seasons prices have been unusually stable. Late-season price declines usually have occurred only after about 80 percent of the crop has been sold.

Factors associated with changes in the seasonal movements of sales and prices are:

A. Long-time factors.

1. *Improvement in transportation facilities.* Trucks and hard-surfaced roads have permitted a much more rapid movement of tobacco to market.

2. *Growth in market capacity.* The Lexington market has increased its warehouses from 8 in 1909-1912 to 25 in 1937-1939, its sets of buyers from 2 to 5, and its average speed of sales from

225 baskets per hour to 360 baskets per hour. Redrying and storage facilities have been increased accordingly.

3. *Changes in competitive buying.* The development of several large companies handling a wide variety of tobacco products seems to have influenced the seasonal movement of Burley tobacco prices. Competition appears to be most active at the height of the marketing season and may influence prices accordingly.

4. *Cumulative effect of high prices early in the season.* Once started, high prices at any time in the season tend to perpetuate themselves, as the more progressive growers try to get their crops or their best tobacco on the market at that time. The peak of prices has moved earlier in the season and so has stimulated earlier marketing.

5. *Change in the type of tobacco.* The light smoking type of Burley tobacco now being grown requires more careful handling than the heavier tobacco grown formerly. It is desirable, therefore, to market it as promptly as possible. The development of this tobacco also has brought a wider range between prices of different grades and thus permits wider fluctuations in average prices on the market.

B. Short-time factors.

1. *Weather.* Weather conditions formerly influenced sales much more than they do today. Better means of transportation plus a large reservoir of warehouse space permits sales to proceed somewhat independently of current receipts.

2. *Annual production.* Large crops usually require a longer selling season than small ones even tho the volume of tobacco sold per week usually is greater from large crops.

3. *Market information.* Forecasts of production which are too high tend to result in the strengthening of prices by grades during the market season. Estimates which are too low tend to result in weaker prices in the season when the true size of the crop becomes apparent.

4. *Quality.* Much of the seasonal variation in average prices is due to seasonal variation in the quality of tobacco sold. Seasonal changes in quality are due in part to differences in the geographical source of tobacco offered for sale during the season and in part to

growers selling their better grades and poorer grades at different times.

5. *Relation between prices by grades.* The importance of quality, as a factor in determining the seasonal movement of average Burley prices, varies from year to year because of variations in the rate of marketing different qualities and differences in the relative prices of the better and poorer grades. When the spread between prices of these grades is narrow, variations in quality have much less effect upon average market prices than when the range is wide.

6. *Restriction of production or market movements.* Control programs under the Agricultural Adjustment Administration in general have tended to stabilize prices during the marketing season but in some cases have resulted in sharp fluctuations.

An analysis of sales and prices by grades revealed that:

1. Tobacco of high quality and light color moves to market somewhat earlier than low quality, dark colored tobacco. Grades of fine and medium qualities and tan color were relatively more important in the early weeks of the season and less important in the later weeks, while common quality and dark-colored grades were relatively more important late in the marketing season. Color is closely associated with quality in the seasonal distribution of sales.

2. Prices of the better grades usually were relatively much more stable thruout the marketing season than those of the poorer grades.

3. Variations in the prices of the medium and low-quality grades appear to be most important in influencing the total money received by an average Burley grower, because of the large amount of tobacco falling in these grades.

4. A large part of the decline in prices toward the end of the marketing season has been due to the poor quality of tobacco offered for sale at that time.

5. The seasonal movement of prices of individual grades sometimes differs considerably from that of average prices for the market as a whole.

Tabulated Data

Table 22. Pounds of Burley tobacco sold on the Lexington market, the average price per hundred pounds and the approximate date of opening and closing the selling season, by years, 1909 to 1939

Crop year	Approximate date market opened closed		Total sales	Average price per 100 pounds
			(1,000 pounds)	(Dollars)
1909	Oct. 11	Apr. 20	20,758	14.19
1910	Oct. 10	May 5	41,786	7.92
1911	Nov. 13	May 11	48,922	10.28
1912	Nov. 18	Apr. 23	40,889	13.23
1913	Nov. 24	Mar. 31	40,139	12.06
1914	Dec. 1	May 29	56,419	8.27
1915	Nov. 30	Apr. 29	35,453	10.53
1916	Dec. 4	Mar. 31	42,217	18.28
1917	Dec. 3	May 11	41,220	28.61
1918	Dec. 9	May 24	55,823	38.40
1919	Dec. 1	May 1	63,667	46.17
1920	Jan. 17	Apr. 30	52,619	13.26
1921	Dec. 12	Mar. 31	10,635	21.49
1922	Dec. 1	Mar. 16	14,800	29.92
1923	Dec. 2	Apr. 18	17,672	22.23
1924	Dec. 1	Apr. 10	19,974	22.60
1925	Nov. 30	Mar. 20	25,348	20.98
1926	Nov. 29	Apr. 16	27,988	14.39
1927	Dec. 5	Mar. 21	47,196	28.27
1928	Dec. 3	Mar. 9	61,247	33.43
1929	Dec. 2	Mar. 15	70,255	22.70
1930	Dec. 8	Apr. 11	67,142	16.70
1931	Dec. 7	Mar. 26	94,818	10.33
1932	Dec. 5	Mar. 11	74,910	13.38
1933	Dec. 11	Apr. 14	81,719	12.32
1934	Dec. 3	Mar. 7	60,328	18.56
1935	Dec. 2	Mar. 21	54,552	19.77
1936	Dec. 7	Feb. 27	55,096	36.56
1937	Dec. 6	Feb. 23	85,248	23.60
1938	Dec. 5	Feb. 18	75,561	21.42
1939	Dec. 11	Feb. 24	89,533	18.86

Table 23. Sales of Burley tobacco on the Lexington market each week, in percent of total sales for the season, by groups of years, 1909 to 1939

Week of season	1909-1912	1913-1916	1917-1920	1921-1926	1927-1929	1930-1934	1935-1937	1938-1939
	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
1	.41	2.08	4.60	5.22	5.21	7.93	11.13	13.20
2	.77	2.85	6.00	7.39	8.12	10.75	14.65	16.93
3	1.54	4.45	8.04	10.10	10.61	12.46	18.19	18.29
4	2.02	7.74	6.89	8.72	10.57	12.51	16.33	17.47
5	3.42	8.54	8.50	10.36	11.72	12.61	15.08	15.34
6	4.42	8.45	8.64	10.08	12.43	12.36	11.82	10.70
7	4.68	9.00	7.96	9.63	11.95	10.75	7.10	5.40
8	5.59	10.52	8.62	7.59	10.92	9.82	3.36	1.86
9	6.58	9.75	8.67	8.01	9.39	6.66	1.49	.64
10	7.45	8.12	10.34	6.32	6.56	2.33	.52	.17
11	6.94	9.17	8.34	5.24	1.70	1.13	.19	
12	7.03	6.78	6.58	3.99	.63	.45	.08	
13	6.65	5.45	3.89	2.68	.12	.14	.03	
14	6.71	3.56	1.48	2.32	.05	.04	.03	
15	6.72	1.42	.73	1.30	.02	.05		
16	5.18	1.00	.42	.70		.01		
17	4.56	.32	.17	.23				
18	4.10	.18	.07	.08				
19	4.55	.07	.03	.03				
20	3.70	.04	.02	.01				
21	1.96	.10	.01					
22	.72	.03	*					
23	.81	.14	*					
24	.97	.08						
25	1.16	.16						
26	.81							
27	.40							
28	.15							
Total	100.0	100.00	100.0	100.0	100.0	100.0	100.0	100.0

*Less than one-hundredth of one percent.

Table 24. Weekly prices of Burley tobacco sold on the Lexington market, expressed in percent of the season's weighted average price, by periods, 1909 to 1939

Week of season	1909-1912	1913-1916	1917-1920	1921-1926	1927-1929	1930-1934	1935-1937	1938-1939
	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
1	91	99	103	103	93	110	97	98
2	90	99	106	100	98	111	120	98
3	92	101	108	103	99	109	123	99
4	93	102	97	103	104	107	110	103
5	98	103	103	104	108	107	90	102
6	101	101	103	104	110	104	78	102
7	106	102	103	104	106	95	71	100
8	106	104	106	101	98	87	65	94
9	101	102	103	98	91	73	55	87
10	102	99	99	96	85	69	50	88
11	104	98	89	94	79	67	*	
12	105	96	82	95	76	59	*	
13	104	97	77	91	65	50	*	
14	102	94	72	82	51	49	*	
15	98	88	69	76	*	40		
16	101	85	59	75		*		
17	97	79	53	75		*		
18	91	85	48	68				
19	87	87	44	*				
20	86	85	39	*				
21	84	88	36					
22	83	*	*					
23	86	*	*					
24	82	*						
25	83	*						
26	83							
27	83							
28	*							

* No prices given when sales occurred in less than half of the years.

[illegible]

Table 26. Weekly average prices of burley tobacco sold on the Lexington market, 1909-1939

Week of season	(Dollars per 100 pounds)														1924	
	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	
1	12.44	9.61	7.05	11.32	12.62	9.28	9.03	16.98	30.79	29.01	60.31	12.97	22.78	28.84	19.72	24.94
2	12.58	9.61	7.58	10.32	12.21	8.74	9.75	17.55	28.33	30.69	66.56	13.52	19.41	30.53	19.59	23.43
3	12.62	8.76	7.91	12.12	12.19	8.77	10.26	17.96	26.59	36.07	59.41	15.44	23.23	30.21	20.49	23.00
4	13.28	8.55	7.99	12.07	12.42	9.06	10.30	17.96	25.25	36.89	48.52	13.12	21.73	29.48	22.38	23.19
5	13.34	8.55	8.59	14.16	13.17	8.73	10.42	17.87	27.12	39.97	52.03	13.12	22.29	30.90	22.98	23.10
6	13.37	8.55	9.08	15.09	13.01	8.11	10.31	18.23	26.36	40.71	53.07	13.03	21.97	30.64	23.60	23.15
7	14.30	8.41	10.54	15.41	12.74	7.71	10.77	19.31	25.69	44.73	51.08	12.64	21.75	30.81	23.78	23.00
8	14.39	8.20	10.70	14.99	12.52	8.08	11.23	19.67	26.87	47.98	44.69	14.33	20.24	30.69	24.13	22.81
9	14.20	8.20	9.65	14.26	12.11	8.14	10.95	19.07	28.01	43.66	42.27	14.35	20.17	29.44	23.97	22.72
10	14.00	8.56	9.99	13.68	12.25	7.96	10.56	18.00	29.40	44.55	37.15	13.07	20.93	28.62	23.89	21.25
11	14.40	8.99	10.48	13.33	11.48	8.02	10.59	18.00	30.28	36.48	38.30	9.72	19.36	29.98	24.03	20.56
12	14.78	8.76	11.04	12.77	10.28	8.35	10.38	17.85	30.95	29.81	35.67	8.48	20.57	30.43	24.26	20.67
13	14.75	8.49	11.82	11.79	10.79	8.76	10.17	17.64	31.26	27.13	29.34	8.71	20.35	29.11	22.73	19.84
14	14.72	8.09	12.06	11.30	9.92	8.25	10.27	17.43	31.37	24.88	21.64	8.63	15.65	28.06	20.77	20.64
15	14.75	8.23	10.53	11.01	8.46	8.26	9.40	17.18	30.73	23.23	23.76	7.69	12.89	27.12	19.22	16.69
16	14.58	8.35	11.40	11.37	8.77	7.48	8.77	17.17	28.79	20.96	15.81		13.34	25.84	18.65	18.30
17	14.37	7.60	11.02	10.91	6.67	7.42	8.77		24.04	18.43	16.76				19.06	19.72
18	14.16	7.34	10.09	9.55	8.23	7.80	8.77		18.00	22.67	13.86				19.05	15.29
19	14.08	6.86	9.24	9.80		7.58	9.47		17.50	19.47	12.65				17.44	
20	14.10	7.15	8.20	9.94		7.12	9.65		17.50	15.52	9.66					
21	14.12	7.57	7.26	9.50		7.63	9.65		17.50	12.84						
22	14.02	7.86	6.53			7.70				14.67						
23	14.90	7.66	7.19			7.34				12.70						
24	14.10	8.01	6.01			7.55										
25	14.10	7.39	7.14			7.13										
26	14.10	7.39														
27	14.10	7.39														
28		7.00														

22.60
22.23
29.92
21.49
13.26
46.17
38.40
28.61
18.28
10.53
8.27
12.06
13.23
10.28
7.93
14.40

week of season	(Dollars per 100 pounds)														
	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
1	22.33	15.68	24.55	31.36	22.19	19.59	11.91	13.42	12.46	21.07	19.98	32.26	23.70	22.83	17.02
2	22.23	15.77	26.29	32.66	23.43	20.14	11.76	14.44	12.95	19.95	21.48	47.79	28.42	22.14	17.48
3	22.00	15.83	25.96	32.32	24.63	19.59	11.13	15.66	11.61	19.90	22.80	50.34	27.65	21.73	18.35
4	21.63	16.02	28.03	33.33	25.74	18.44	10.44	15.39	12.14	20.06	22.24	40.83	24.90	21.19	20.10
5	22.66	15.23	29.34	35.13	26.23	18.37	11.12	14.55	12.54	19.43	20.19	28.75	21.06	21.08	20.02
6	22.34	14.92	30.65	37.38	24.83	17.34	10.71	13.41	13.64	18.63	17.93	24.02	18.13	20.78	20.21
7	22.19	14.91	30.50	36.72	22.43	14.51	10.66	11.51	12.50	18.42	16.09	22.73	16.64	20.26	20.07
8	20.71	14.47	29.51	34.47	19.95	12.03	9.27	10.05	12.75	17.15	14.49	18.74	16.87	18.51	19.17
9	19.19	14.22	28.40	28.85	19.56	10.82	6.65	9.09	9.94	15.93	12.93	14.23	14.29	17.33	17.43
10	18.06	13.77	26.77	27.21	17.96	10.27	5.40	7.54	11.34	14.94	11.87	10.78	15.45	18.60	17.00
11	17.06	13.85	23.96	26.41	16.67	10.67	5.36	9.22	10.95	11.03	10.46				
12	16.83	13.51	22.48	25.85	16.46	9.78	4.12	8.37	10.48	9.14	8.30				
13	15.46	13.21	20.70	20.19	13.98	8.60	3.49	6.83	9.36	7.26	5.38				
14	11.67	12.51	17.50		10.20	8.14	4.87		7.03		5.75				
15	13.58	11.61	17.50			8.33	3.51		5.05						
16		10.34				6.68									
17		9.39				5.28									
18		9.01													
19		7.78													
20		8.00													
Season	20.98	14.39	28.27	33.43	22.70	16.70	10.33	13.38	12.32	18.56	19.77	36.56	23.60	21.43	18.86

Table 27. Prices of Burley tobacco sold on the Lexington market each week, in percent of the season's weighted average price, by years, 1909 to 1939

[illegible]

[illegible]

Kentucky

Agricultural Experiment Station

University of Kentucky

THE EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH OF APPLE AND PEACH TREES IN SAND CULTURE

BULLETIN NO. 410



Lexington, Kentucky

December, 1940

(487)

C O N T E N T S

	Page
Introduction	489
Review of literature	490
Response to nitrogen	490
Response to phosphorus	490
Nitrogen deficiency	491
Phosphorus deficiency	499
Experimental procedure	501
Composition of the nutrient solutions	502
Growth measurements	508
Chemical analyses	508
Methods of analysis	509
Results	510
Growth	510
Chemical analyses	530
Reaction of the nutrient solution	531
Deficiency symptoms	531
Nitrogen deficiency symptoms	531
Phosphorus deficiency symptoms	531
Summary	541
Literature cited	541

THE EFFECT OF NITROGEN AND PHOSPHORUS ON
THE GROWTH OF APPLE AND PEACH
TREES IN SAND CULTURE*

By C. S. WALTMAN

INTRODUCTION

Much work has been done with fruit and vegetable plants of various kinds to determine the influence of nitrogen and phosphorus on growth and fruiting ability. Certain rather definite relationships have been found to exist between the available nitrogen supply and vegetative growth and likewise between vegetative growth and fruit production. In the same way, phosphorus has been shown to influence these conditions in certain respects and to have a rather marked influence on the root development of plants and on certain other characteristics that are associated with growth and fruit bearing.

During comparatively recent years many research workers have turned their attention to a study of plants grown in artificial media in which nutrient materials of various kinds could be supplied in the amounts desired and observations and determinations made to show the characteristic symptoms and conditions which develop in the absence or overabundance of certain elements. In short, the plants have been grown under controlled conditions where the worker has found it much easier to diagnose the cause of certain physiological disorders and then to use this information for the correction of similar troubles found under field conditions.

As stated in the work of Alexander, Morris and Young (1), the growth of plants in water culture and other media is an old practice. "In 1679 Edde Mariotte grew plants in water and found that they required earthly salts, nitre, and ammonia, and John Woodward in 1692 published the first definite account of growing plants without soil. Dunhamel, in 1758 was the first to grow plants to maturity in water culture. However, it was not until

*The author wishes to express his appreciation to Dr. A. M. Peter for many helpful and valuable suggestions offered on the arrangement of tables and tabulation of results and for the constructive criticism given during the preparation of the manuscript.

after the discovery of nitrogen, hydrogen and oxygen in 1785 that definite steps in the nutrition of plants were made."

Much information can be found in recent literature as to the effect of various nutrient elements on growth and composition of different plant parts; and many reports have been written regarding the symptoms of malnutrition.

The purpose of this investigation was to determine the influence of nitrogen and phosphorus in varying amounts on the growth of apple and peach trees in sand culture and to study the characteristic symptoms which develop when these materials are omitted from the nutrient solutions or when they are used in quantities considered excessive. In a previous publication (88), the seasonal course of soluble nitrogen and phosphate phosphorus in apple and peach shoots of orchard trees under several cultural practices and different fertilizer treatments was reported. The investigation herein reported was done as supplementary to the previous work.

REVIEW OF LITERATURE

Response to Nitrogen. The general effect of nitrogen is to promote vegetative vigor, increase leaf area, produce development of deep green color in the foliage, cause leaves to be retained longer on the trees and improve the set of fruit. It is the nutrient element most likely to be in insufficient quantities under average conditions and in many cases proves to be a limiting factor to successful production. Gardner, Bradford and Hooker (32), Chandler (12), Cooper (17), Armstrong (2), Hooker (42), Murneek (57) and others have pointed out that nitrogen fertilizer used with both apple and peach trees has resulted in increased vegetative activity, greater leaf area and an increase in the amount of bearing surface. Trees growing under conditions where the supply of available nitrogen is abundant develop darker colored foliage than under conditions where the available supply is limited. Proebsting (61) working in California, has found that nitrogen influences the amount of shoot growth, the abundance of foliage, the color of leaves, the time of leaf fall and the time of fruit maturity. Reports have also been given which show that trees which have made poor growth because of an insufficient supply of nitrogen are more subject to the attacks of some insect pests and are also less able to survive conditions of severe winter cold.

Heinicke (36) has shown that the nitrogen requirement of a large apple tree producing 25 bushels of fruit is 3.9 pounds, and Magness (52) has calculated a necessary nitrogen intake of 1.5 to 1.75 pounds per tree per year. According to Magness, part of this intake may be returned to the soil in the form of blossoms, leaves, fruits etc., but approximately one pound per tree per year is permanently removed from the soil. Magness emphasizes that these figures refer to nitrogen intake and not fertilizer applications and that the intake under certain soil conditions and with certain cultural practices may be much less than the amount applied in the form of fertilizer.

Howlett (43) found that the sodium-nitrate equivalent of the total nitrogen withdrawal up to full bloom by the total number of flowers on twenty- to thirty-year-old trees would range from .5 to 1.20 pounds and that this represents only a part of the nitrogen necessary for growth of the tree and development of the fruits to maturity. In his work he found but little withdrawal of nitrogen by flowers during the period of full bloom.

Lagasse (45) studied the nitrogen-carbohydrate ratios in apple trees and found in general that trees which received three pounds of nitrate of soda in the spring, alone or in combination with acid phosphate and muriate of potash, were much deeper green and made better terminal and spur growth than where no nitrate was used. He also found yields to be noticeably increased by the treatment.

VanSlyke (84) reported as early as 1905 on the total quantity of nitrogen required by some apple varieties and estimated that for heavy-bearing Baldwin trees 1.413 pounds per tree would be needed and for Rhode Island Greening 1.527 pounds per tree per year would be used.

Williams (92) made nitrogen determinations of apple trees which had been fertilized with nitrogen and found an increased amount of total nitrogen in shoots as a result of the fertilizer application. The amount of the increase was determined largely by the time of the fertilizer application. Three pounds applied in March definitely increased the percent of total nitrogen in the tree early in the season and when three pounds were applied after harvest it gave a high nitrogen concentration in the shoots which was maintained during the remainder of the season.

Sullivan and Cullinan (71), Sullivan and Baker (72), and Baker (4), have made extensive studies of the response of apple trees to nitrogen fertilizer and found terminal and trunk growth to be correlated with the nitrogen content of the trees. They found that cultivated trees with a cover crop, without organic fertilizer, made greater growth and contained more nitrogen than trees in bluegrass sod that received a nitrogen fertilizer. In their tests they found that trees in bluegrass made slower growth and came into bearing later but eventually surpassed the cultivated plot in growth, yield and nitrogen content. Sullivan (71) reported on the analysis of shoots from Grimes Golden trees and recorded the greatest total nitrogen content in trees that received tillage and a cover crop. He found these trees to have a greater total nitrogen content during the growing season than trees in sod or in alfalfa. The trees in sod showed the lowest amount of total nitrogen in spite of the fact that they were the only trees that received inorganic nitrogen fertilizer and the leaves on these trees were light green and terminal shoot growth was short. Sullivan found that the difference in total nitrogen between different plots was much greater during the active growing season than during the dormant season.

Under average conditions trees that are well supplied with nitrogen will make good growth and produce leaves that are synthetically active unless some adverse condition such as poor drainage, shading etc., prevents it. Thus Kraus and Kraybill (44) have pointed out in their outstanding study of the nitrogen-carbohydrate relationships in the tomato, that even tho an abundance of amino acids and other forms of soluble nitrogen is present, which may not necessarily include nitrate, yet without an available supply of carbohydrates there may be decomposition of protein. Vegetation is then weakened and the plants are not fruitful. Remy (63) has pointed out that if the nitrogen is below a certain level fruit-bud differentiation is hindered.

In studies somewhat similar to those of Kraus and Kraybill, Laurent (46) and Godlewski (34) found that nitrate could be assimilated in darkness to amide compounds but not to protein and that protein synthesis could occur only in the presence of light.

Nightingale (58), working with several different kinds of plants found that nitrate is not necessarily associated with the growth response of plants and that tomatoes with no nitrate in the nutrient

culture or tissues of leaves, stems or roots grew rapidly when the carbohydrate supply was increased by subjecting the plants to short-day conditions or to total darkness. This investigator was of the opinion that nitrate in these plants may have been formed from the decomposition of protein or some other nitrogen compound.

With regard to the use of nitrogen fertilizer applied in the fall to fruit trees, most investigators are of the opinion that such applications do not tend to increase the percent of nitrogen found in the shoots during the dormant season. In fact, Roberts (66) points out that the absorption of large quantities of nitrogen late in the season might cause chemical changes in the tissues that would reduce resistance to winter cold. Roberts' findings seemed to indicate that as nitrogen was taken up there was a change in the carbohydrates even before these materials could be used in growth.

In some fall-fertilized Elberta peach trees at Lexington (89) only those fertilized with sulfate of ammonia showed an increase in soluble nitrogen during the dormant season, over the check trees. In fact, trees treated with cyanamid and sodium nitrate showed a decrease in their percentage of soluble nitrogen in comparison with the untreated checks. There was a downward trend during the winter in soluble nitrogen in peach twigs of all trees regardless of fertilizer treatment. The average for 24 weeks during fall and winter was lower than the percentages found in the same groups of trees before they were fertilized with nitrogen in the fall.

Several investigators have determined the nitrogen content of leaves, stems and roots of young trees during the latter part of the growing season and Combes (16) found that leaves undergoing senescence on the tree lost much of their nitrogen, while those yellowing off the tree lost very little even tho attached to a piece of the branch toward which nitrogen would normally move. He found that part of the nitrogen which passes back from the leaves accumulates in the branch near the point where the leaves are attached. He also concluded that nitrogen migrates in the fall from the leaves to the stems and then to the roots and he even ventured the suggestion that under certain conditions the roots may excrete nitrogenous substances into the soil. Both Combes (16) and Le Clerc (47) are of the opinion that the problem of what becomes

of the nitrogen compounds at the time leaves are yellowing can only be solved by making an analysis of the branches and preferably the whole tree or plant. In the first part of this work, during which the seasonal course of soluble nitrogen was determined in shoot growth of Winesap apple and Elberta peach (88), it was found that soluble nitrogen averaged considerably lower during the winter, in both apple and peach, than during the active growing season. The nitrogen was considerably higher in peach shoots during the winter than in apple and the content in apple shoots was maintained at a relatively constant low level during the winter. At least, between the apple and the peach, there appears to be a close relationship between the soluble nitrogen content of winter shoots and the ability of the plants to resist winter cold.

Ripple (64) made studies of the transfer of nitrogen from the leaves and found that the nitrogen compounds which are translocated from the leaves are largely proteins, especially those forming the chloroplasts. He found the highest content of nitrogen in leaves in June and the lowest at the time of chlorophyll degeneration. Under conditions where nitrogen was deficient he found leaves beginning to yellow early in the season with the oldest leaves yellowing first. He indicated that the younger leaves may absorb nitrogen from the older, weaker ones.

Similar determinations were made by Murneek and Logan (56) and they concluded that nitrogen migrates from the leaves into the spurs and branches where it may be laid down temporarily in the form of reserve protein and that the removal of nitrogen from the leaves is due primarily to a decrease in the water-insoluble fraction. They found that eventually the nitrogen is translocated to the older wood and possibly to the root system. Murneek found that the amount of nitrogen translocated from the leaves to other parts of the tree may amount to as much as 22 to 40 percent. Weather conditions, according to their opinion, greatly influence the translocation of nitrogen, particularly its initiation and speed of movement. They found that cool weather appeared to hasten it but a killing frost destroyed the process.

Loomis (51) in his investigational work found large quantities of protein nitrogen stored in the bark and wood of trees when it was digested and used in early spring growth. He considered the success of fall nitrogen applications and the cumulative effect

of nitrogen fertilization with ammonia as probably related to this storage. He found that nitrogenous salts appeared to be synthesized to organic compounds in the roots of apple and other trees and as a result of this synthesis, to be readily translocated only in the phloem tissue. He found, that as a result of this, ringing stops the upward flow of nitrogen as well as the downward movement of carbohydrates. Studies of similar nature have been conducted by Curtis (19) (20) and Murneek and Logan (56).

Thomas (73) thinks that the nitrogen content of leaves of the apple begins to decline as soon as active growth ceases. He found the most rapid decrease to occur during yellowing and that it continued until defoliation was complete. His findings seem to indicate that storage is mainly in one- and two-year-old wood. In another study Thomas (75) found that nitrogen accumulated in one- and two-year twigs of the apple during the late dormant season and as growth started this nitrogen moved into the new shoots and leaves, depleting the tissues of the twigs. Similar results were found by Waltman (88) for apple and peach and by Piney (59) who studied the new growth of beech.

Results similar to those just mentioned were obtained by Traub (82) who found that the nitrogen maximum is reached in March or April just preceding rapid growth extension. After the marked decline in nitrogen with rapid growth extension the nitrogen content is relatively constant during the summer. It was also practically constant during the dormant season. He found that the dormant-season content of nitrogen is largely non-amino or protein nitrogen and decreases as the active growing season approaches and reaches a minimum usually in June.

Childers and Cowart (14) and several other investigators have shown that the photosynthetic activity of leaves is considerably influenced by their chlorophyll content and this in turn is affected by the available nitrogen supply. Iron also plays an important part in chlorophyll formation and altho it is not a part of the chlorophyll molecule an available supply is necessary because it serves as a catalyst. Nitrogen is an essential element in the development of chlorophyll being a component part of the chlorophyll molecule. Plants which are well supplied with nitrogen make more vigorous growth because of their greater ability to synthesize more food.

Response to Phosphorus. In general, the response made by plants to applications of phosphorus fertilizer is less pronounced than to nitrogen altho certain well-defined symptoms characterize plants growing under conditions where the phosphorus supply is deficient.

Russell (67) states that the most obvious effects of phosphorus are on the root system and the production of seed. Plants well supplied with this element have much greater root development and produce seeds in a satisfactory way. Russell points out that phosphates are the most important phosphorus nutrients and that they tend to hasten the ripening process. Phosphorus appears to be essential to mitotic cell division, probably because it is a constituent of the nucleus and is necessary also for the normal transformation of starch. Apparently starch may form in the absence of phosphorus but does not change to sugar. Russell states further that phosphorus appears to increase the development of meristematic tissue and the efficiency of the chloroplast mechanism.

It is suggested by Gardner, Bradford and Hooker (32) that the elaboration and assimilation of phosphorus, like nitrogen, appears to take place in the leaves, for the most part. The amount of phosphorus assimilated is stated to be closely related to the amount of illumination the plant receives and appears to be connected with photosynthetic activity. They point out that the elaborated phosphate compounds occur in nucleic acids, nucleins and nucleo-proteins, substances always present in the cell nucleus and considered to be associated with various enzymes in all plant tissues. They state that most tissues contain approximately six times as much nitrogen as phosphorus. There is a suggestion that both nitrogen and phosphorus may be combined in the same molecule, altho phosphorus apparently does not play the same part as nitrogen in plant metabolism. These authors quote the work of Harris who says "It has been shown by several investigators that the content of phosphorus is generally low in acid soils and largely unavailable for use by plants." This condition is further explained by Stoddart who says that acid soils convert any calcium phosphate that may be present into soluble compounds which are either washed out or are fixed in an insoluble form by the formation of iron and aluminum phosphates.

Several investigators, including Blake, Nightingale and David-

son (10), have found that a deficient supply of phosphorus to young apple trees resulted in a high accumulation of carbohydrates in both tops and roots. These workers found, however, that the trees eventually became low in starch and proteins and high in sugars.

Lilleland (48), in California, grew peaches in soils that were exceptionally low in phosphorus. He found that treated trees retained their leaves longer in the fall than the untreated check trees; however, the phosphorus fertilizer did not affect the time of bloom, time of ripening or the amount of shoot growth. He found a yellowing of the foliage which appeared to be due to a depression of nitrogen absorption caused by the addition of phosphorus. Proof was added to this assumption by the analysis of leaves, which showed a lower nitrogen content in phosphorus-treated trees. Results somewhat similar to these were obtained by Thomas (74) (75) who found lower P/N ratios in apple trees in tanks where nitrogen had been added. He also found a greater amount of phosphorus absorbed by these trees.

Further work by Lilleland (49), in California, on soil low in phosphorus, gave striking results in increased shoot and root growth from phosphoric applications on several species of fruit. Shoot growth of apples was increased 79 percent, apricots 66, prunes 39, and peaches 105 percent. Apple root growth was increased 37 percent, apricots 44, prunes (apricot roots) 42, and peaches 80 percent. He found the top-to-root ratio to be increased on apples by the phosphorus application but obtained no significant difference on the other species.

Scott (69) found that in a sandy soil in South Carolina the omission of phosphorus to peaches did not show striking differences from the fertilized trees. However, the trees which received no phosphorus yielded significantly less, grew more slowly and showed poorer fruit-bud development. In this experiment an unsatisfactory growth of rye cover crop resulted on the plots where phosphorus was not used. Similar comments on cover crop growth under conditions where the phosphorus supply is limited are offered by Chandler (12) and others.

Nitrogen Deficiency. Deficiency in the nitrogen supply usually results in poor, weak growth, small, yellowed leaves and generally poor fruit development. Childers and Cowart (14) state that

"Any nutrient which directly or indirectly influences leaf color, stomata or other characteristics of foliage would be expected to influence the leaf activity." Thus, they found that leaves deficient in nitrogen assimilated about one-third as much carbon dioxide and transpired about 70 percent as much water as did the full-nutrient leaves. Their trees were grown in washed sand in a greenhouse and those which received no nitrogen developed the most striking symptoms. The leaves were small and light green; none of the shoots grew more than twelve inches long and all formed terminal buds early. Similar results were obtained by Blake, Nightingale and Davidson (10) (11) with one-year-old Blaxtayanman root-grafted apple trees grown in sand cultures in six different nutrient treatments. The lack of an external supply of nitrogen was associated with an early appearance of yellowish-green leaf blades and a reddening of veins of lower leaves. The upper leaves later exhibited this condition and all leaves assumed an upright position with the petioles forming narrow angles with the stems. The angles formed by the leaf petioles with the main stem became more and more acute as growth continued. These investigators noted similar results in their study of growth of Delicious apple trees under field conditions (9) also the leaves became more brittle as they developed the yellowish-green color. The cambial activity of these trees was very limited and ceased early in the season, resulting in short shoots of small diameter. The carbohydrate accumulation was high and root growth extensive, woody and abnormally slender. In the second season new growth was very slow and weak and finally the trees produced a few small, spindly branches 2 to 6 inches long. The new growth developed from the original tree base rather than from the previous season's growth. The new leaves were thin, narrow and definitely yellow from the time of their first appearance.

With peach trees grown in sand, Davidson and Blake (21) obtained results similar to those with apples. Shoot growth was restricted in length and diameter and the older leaves first yellowed and later the young leaves lost much of their green color. Typical purplish-red spots developed on the foliage and the cell walls were abnormally thick. Carbohydrates accumulated rapidly in the tops, and roots were yellowish and slender but fairly extensive.

Davidson and Blake (22) point out in another publication

that the development of a nutrient-deficiency symptom is dependent primarily on two factors: "(a) the rate of growth of the trees and (b) failure of the root media to supply the limiting nutrients in amounts and proportions adequate for that rate of growth."

The results found by Blake and his co-workers were obtained also by Weinberger and Cullinan (91) Fisher (31) Wallace (85) and Hoagland and Chandler (39). Weinberger and Cullinan emphasized that there were no complete descriptions of the symptoms produced in peaches by lack of mineral elements, except phosphorus and potassium. With their trees which received no nitrogen a large number of fibrous roots were formed. They found relatively three times as much fibrous root growth by weight in proportion to top as for trees in complete nutrient solution.

Part of the work by Fisher (31) was with tomato plants which were given a culture containing excess nitrogen. This treatment stimulated vegetative growth at the expense of flowers and fruit. Terminal shoot growth of these plants was depressed but lateral branches were numerous and but few fruits were set. The leaves were spotted with dead areas, curled, roughly pimpled and yellowed interveinously. The time of maturity was greatly delayed and resistance to disease and insects reduced. Root growth was light brown with few branches.

Under certain conditions it appears that the continued use of certain nitrogen fertilizers may produce physiological disorders. Rawl (62) reports on a case of this nature in a sandy soil in South Carolina where sulfate of ammonia alone had been used continuously over a period of years, and certain characteristic symptoms developed. The trees grew poorly, did not form fruit buds properly and produced low yields of small peaches. The leaves first changed to a yellowish light green, later to a very pale yellow, followed by burning or scorching of the tips and leaf margins. Tests of pH on the soils indicated that the continued use of sulfate of ammonia had resulted in high soil acidity. Complete fertilizers applied to these trees produced good growth and good yields of marketable fruit. The experiment was not arranged to show whether phosphorus or potassium gave the greatest benefit in affecting recovery of the trees.

Phosphorus Deficiency. The general effect upon plants of an

insufficient supply of phosphorus is less pronounced and probably in some respects less serious than for nitrogen. The fact that fruit trees frequently fail to show ready response to phosphorus applications under conditions where grain crops make noticeable gains, can probably be accounted for in one of three ways: (1) tree roots penetrate deep, if soil conditions permit, and in that way probably obtain part of their phosphorus supply from lower soil levels; (2) trees may actually use considerably less phosphorus than the shallow, fibrous-rooted grain crops; (3) trees may be able to use their phosphorus in a different form from that required by plants of the grass family. In any event, there are conditions under which fruit trees develop symptoms of phosphorus starvation and considerable work has been done in recent years by means of artificial media which emphasize these characteristic symptoms so that they may be more readily recognized under field conditions.

The work of Blake, Nightingale and Davidson (10) (11) (21), Weinberger and Cullinan (91), Wallace (85), Hoagland and Chandler (39), and others, shows that phosphorus deficiency symptoms, in the early stages, are very similar to those of nitrogen starvation, except that decided yellowing of the foliage is not common. The upper leaves usually remained dark green with the mid-ribs, veins and petioles definitely tinged with purplish-red. Shoot growth was generally very slender and young leaves thin, small, dark green and tinged with purple. The green color of leaves where phosphorus was deficient was lacking in the luster characteristic of the foliage on plants making vigorous growth. Fibrous root growth was restricted by a deficiency of phosphorus and roots that formed were slender and contained an abundance of nitrate. Carbohydrate, largely sugar, accumulated in both tops and roots and was found in greatest amount near the tips of new growth.

Davidson (23) found that under some of the soil conditions of New Jersey, peach trees may develop deficiency symptoms of phosphorus and a base at the same time. In sand cultures, his studies indicated that phosphorus deficiency in peach trees develops independently of, or may coexist with, deficiencies of calcium, potassium or magnesium. Omission of phosphorus resulted in an increase in pigmentation and in the formation of narrow, dark ochre-green leaves, almost regardless of whether or not the treatment was also deficient in a base.

Leaves deficient in phosphorus are affected much less in their photosynthetic activity and transpiration rate than those deficient in nitrogen. This was shown by Childers and Cowart (14) who concluded that nitrogen plays a much more important role in photosynthesis and transpiration of apple leaves than phosphorus or potassium, alone or combined.

EXPERIMENTAL PROCEDURE

Two varieties of apple and one of peach were used in this experiment. The apples were one-year-old grafted trees of the Staymared and Paducah varieties and the peaches were one-year-old Elberta trees. The trees were selected for uniformity from nursery stock of our own propagation and were taken directly from the nursery rows. They were treated uniformly as to top and root pruning and placed in the culture jars containing a high grade of washed, sharp sand. The trees were selected in March after having grown one season in the nursery and were washed free of all soil and the root system pruned so that all fibrous roots were removed and only moderate-sized roots left. The apple tops were cut back to a height of approximately fifteen inches and the lateral growth on the tops of the peach trees was reduced to stubs about an inch in length and these were thinned so that there was an opportunity for about five buds to start from each tree trunk.

The cultures consisted of seven different nutrient solutions with variations in the content of nitrogen and phosphorus and were applied in such a way that one tree of each of the apple varieties and two peach trees received the same nutrient treatment. The nutrient elements other than nitrogen and phosphorus were supplied to all trees in equal amounts. Three-gallon stone jars provided with a drainage hole in the bottom were used and 14,500 grams of sand were placed in each jar. A cork stopper containing a small glass tube was placed in the drainage hole so that a quantity of the solution from the sand could be collected for pH determination when fresh solution was added to the jars.

The jars were arranged out-of-doors, on a framework supported by small sawhorses. To provide a satisfactory cover for the jars, two pieces of board were used for each jar, cut in a semicircular form somewhat larger than the diameter of the jar. The straight edges

were then beveled and small nails driven at the lower circular edge of each board to hold the halves in position. In this way the beveled edges were held together and the boards were held by the nails against the inside edge of the jar so that they provided a sloping cover for each container. A notch was made in each half of the cover, for the tree.

After the board covers were in position, a piece of heavy mulch paper was placed over each one and fastened to the boards by means of thumb tacks. To further prevent water entering the jar at the center of the cover where the tree trunk emerged, a pad of cotton was pushed into the hole between the tree and the board. Trouble was experienced in this connection by sparrows pulling the cotton from around the trees, so a one-hole rubber stopper split open on one side, was set around each tree on top of the cover and over the cotton. On several occasions during the course of the experiment, weighings were made before and following heavy rains and at no time did water enter the jars.

The sand used was a moderately fine grade of white glass sand obtained from West Virginia. It was thoroly washed with tap water and then with distilled water, and dried. It was found by chemical tests to contain no nitrogen or phosphorus. The analysis of sand* showed it to run 99.58 percent silica with very small percentages of iron and aluminum oxides. In a previous experiment with strawberries (86) this medium was found to be entirely satisfactory for plant growth. For an experiment of this nature sand appears to be the most satisfactory medium and has been recommended and used successfully by many investigators (11) (13) (25) (54) (65) (70).

Composition of The Nutrient Solutions. Many kinds of nutrient solutions have been suggested by investigators who found them suited to their work. It appears probable that a solution containing all the necessary nutrient elements in proper proportions for general plant growth may not give equal results with different species of plants. For example, in the assimilation of nitrogen, it has been shown by Pirschle (60) and by Tiedjens and Robbins (77) that many crop plants can assimilate ammonium

*Supplied by the firm in West Virginia from which the sand was obtained. A test here at this Station showed 99.85 percent insoluble in hydrochloric acid.

and nitrate provided the hydrogen-ion concentration of the nutrient solution is suitable to the form of nitrogen used. It appears further that the necessary pH value may be specific for each species. Tiedjens and Blake (79) state that it appears that pH values below 6 generally favor nitrate assimilation and values of 6 or above favor ammonium assimilation. Studies which have indicated similar results regarding nitrate assimilation have been made by Baudisch (7) (8).

Tiedjens and Blake (79) found that apple trees absorbed and assimilated ammonium nitrogen without oxidation to nitrate and that the hydrogen-ion concentration of the culture medium limited, directly, or indirectly, the assimilation of both ammonium and nitrate. Their studies indicated that in soils where the pH value was comparatively low ammonium was apparently oxidized to nitrate before assimilation of nitrogen occurred. Under conditions where the pH of the culture medium was favorable for ammonium and nitrate, respectively, ammonium produced a more rapid growth response than nitrate.

In a study of the effect of different nitrogen carriers on the performance of apple trees, Batjer and Sudds (6) found that trees made greater root growth where nitrate of soda was used in place of sulfate of ammonia. In their experiment, root growth on nitrated trees was often more than twice as much as on sulfated trees. They found also that the soil was much more acid where sulfate of ammonia had been used.

Studies similar to those of Batjer and Sudds were made by Clark and Shive (15) with tomato plants. Their findings showed that the concentration of ammonium nitrogen in the roots varied with the pH of the external medium. Higher concentrations of ammonium nitrogen were present in the roots of plants grown in solutions of high pH than in those grown in solutions of low pH. High concentrations of ammonium in the roots accompanied high rates of absorption of ammonium from the solutions.

The work of Tiedjens (78) indicated that the nitrate ion was assimilated most satisfactorily by tomato and apple when absorbed from an acid nutrient solution of approximately pH 4.00. The ammonium ion was assimilated most satisfactorily when absorbed from a nutrient solution having a constant pH value of 5.0 to 6.5, vary-

ing somewhat with the variety. He found that ammonium ions were immediately absorbed by plants without further change and were assimilated directly and more rapidly than the nitrate ion, and that the volume of growth obtained from nitrate and ammonium depended on the concentration of the nitrogenous salt in the nutrient solution and the available carbohydrates. Under conditions where a large amount of carbohydrate was available, ammonium was assimilated more rapidly than where the supply of available carbohydrate was small.

In an experiment with strawberries and sand culture (86) in which ammonium nitrate was used to furnish the nitrogen, the plants grew best at a reaction of pH 5.3 to 5.5. The nitrogen content of this solution was 242 ppm.

Work by Emmert (30) at the Kentucky Station, with tomatoes and lettuce grown in treated soil, gave variable results as to the best pH for plant growth and yield. With tomatoes, the heaviest yields were produced by the use of sodium carbonate added to the soil to maintain a pH of 8.3 to 8.4. The second heaviest yield resulted from the use of the same material where the pH was maintained at 7.3 to 8.0. The heaviest lettuce yields also were produced where sodium carbonate was applied to maintain a pH of about 7.5. It seems probable that some other effect than on pH value may have occurred from the use of sodium carbonate on this soil.

The results obtained by Hoagland (38) were similar to those of Tiedjens and Blake (79). He found that the reaction of a culture solution has an important bearing on the absorption of ions. He observed that the absorption of the NO_3 ion was favored by an acid reaction and that nitrate penetrated far more rapidly into the cell sap of some plants from an acid than from an alkaline solution. He further emphasized that the hydrogen-ion concentration may be one of the chief variables governing the colloidal behavior of the protoplasm of the cell. This view is further strengthened by Chandler (12) who points out that in winter-injured tissue there is an increase in hydrogen-ion concentration of the cell sap, accompanied by a disruption of the colloidal stability of the protoplasm.

The maintenance of a reaction that is most suitable to the growth of plants is difficult under soil conditions largely because of the buffer action of the soil. In artificial cultures of either sand

or solutions a definite, stable pH is maintained more easily, altho several things have an influence on it. Trelease and Trelease (81) state that "the solution constituents that have the most pronounced influence upon reaction changes are the nitrates or ammonium salts employed as sources of nitrogen for the plants." Working with wheat plants in solution cultures, they obtained best growth at an approximately stable pH value of 5.1. Their cultures were arranged at pH values of 4.3, 5.1 and 6.0 and were maintained at these values by varying the ratio of NO_3/NH_4 in the solutions. The NO_3/NH_4 ionic ratios of 50/50, 80/20 and 90/10 were used to obtain the initial pH values indicated above. The salts employed were KNO_3 and $(\text{NH}_4)_2\text{SO}_4$. With the lower NO_3/NH_4 ratio the pH value of the solution decreased rapidly under influence of the plants and approached in extreme cases a pH value of 3.0. With the higher ratio, the pH value increased rapidly, tending to reach a limiting value of 6.5.

They state that "The anions of the nitrates, together with H ions derived from the solution, are absorbed by the plant more rapidly than the cations, thus tending to decrease the hydrogen-ion concentration. On the other hand, the ammonium salts have the opposite effect; their cations enter the plant more rapidly than their anions, and the hydrogen-ion concentration is thereby increased, regardless of whether the actual absorption of the cations occurs in company with OH ions derived from the solution or whether NH_3 , resulting from a decomposition of $(\text{NH}_4)\text{OH}$, is absorbed by the plant." They found that young plants seem to remove NH_4 ions more rapidly than NO_3 ions.

Scofield (68) calls attention to the point that plants do not absorb water and dissolved substances from the soil solution in the same proportions that these constituents occur together in that solution. This evidently has a direct bearing on the absorption of different salts by plants growing in either sand or solution cultures.

Blake, Nightingale and Davidson (11) adjusted to pH 4.2 the nutrient solution to be used for apple trees in sand culture, and found that between the times when additional solution was added, the solution in the sand tended to become less acid, about pH 5.0 to 5.2. They found in previous work (79) with young apple trees, that the pH range indicated above was excellent for growth with the nutrient solution which they employed.

Suggestions for balancing nutrient solutions, their adjustment to a suitable reaction and the preparation of special equipment for use in growing plants in sand and solution cultures are offered by Turner and Henry (83), Davis and Hoagland (24), Hill and Grant (37), Hoagland and Arnon (41), McCall (55), and Shive and Robbins (70).

In the preparation of the nutrient solutions used in this experiment it was desired to have variations only in the content of nitrogen and phosphorus. With this point in mind the solutions were arranged as follows:

1. Basal (complete).
2. No nitrogen.
3. Low nitrogen, $\frac{1}{4}$ as much as No. 1.
4. Excess nitrogen, twice as much as No. 1.
5. No phosphorus.
6. Low phosphorus, $\frac{1}{4}$ as much as No. 1.
7. Excess phosphorus, twice as much as No. 1.

A modification of the solution used by Blake, Nightingale and Davidson (11) was employed and iron was supplied to all solutions by the use of ferric citrate. One cc of a 0.5 percent solution of this material was used for each liter of solution at the time they were made up. This procedure has been found satisfactory by Marsh and Shive (53) and by Weinberger and Cullinan (91). At the beginning of this experiment and continuing for a period of ten days after the trees were set in the jars, only distilled water was added. This gave a chance for the reserve materials within the trees to be used before any nutrient solutions were supplied. After the trees had started to grow, the nutrient solutions were supplied at the rate of approximately 500 cc every other day during the first few weeks of the experiment. This amount of solution added to the jars resulted in the leaching of 50 to 100 cc which was collected each time for pH determination. As the season progressed and the trees grew, fresh solution was added to each jar each day and the amounts gradually increased. One tree of each of the apple varieties and two peach trees received the same nutrient treatment.

Table 1 gives the chemical compounds used, in grams per liter, and table 2 the concentration of the elements in each of the nutrient solutions used, in parts per million.

The concentration of elements in these solutions varies some-

what from those employed by Blake, Nightingale and Davidson (11) particularly in the content of nitrogen and chlorine and in the absence of sodium. Under field conditions, where sodium nitrate is commonly used as a fertilizer, there is undoubtedly an accumulation of sodium in the soil which tends to cause an increase in the pH value. In the humid sections of the country the sodium is

Table 1. Composition of the nutrient solutions, in grams per liter.

Compound	Basal	No ni- trogen	¼ ni- trogen	2 ni- trogen	No phos- phorus	¼ phos- phorus	2 phos- phorus
KH_2PO_4	0.2995	0.2995	0.2995	0.2995		0.0749	0.2995
$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	0.6456	0.6456	0.6456	0.6456	0.6456	0.6456	0.6456
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	0.5878	0.5878	0.5878	0.5878	0.5878	0.5878	0.5878
NH_4NO_3	0.6400		0.1600	1.2800	0.4629	0.5143	0.4629
KNO_3					0.2224	0.1655	
$(\text{NH}_4)_2\text{H}_2\text{PO}_4$							0.2523
$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180
H_3BO_3	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171
$\text{FeC}_2\text{H}_3\text{O}_7 \cdot 3\text{H}_2\text{O}$	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050

Table 2. Nutrient elements in the solutions, in parts per million.

Element	Basal	No ni- trogen	¼ ni- trogen	2 ni- trogen	No phos- phorus	¼ phos- phorus	2 phos- phorus
Potassium, K	86	86	86	86	86	86	86
Calcium, Ca	176	176	176	176	176	176	176
Magnesium, Mg	58	58	58	58	58	58	58
Manganese, Mn	5	5	5	5	5	5	5
Iron, Fe	1	1	1	1	1	1	1
Phosphorus, P	68	68	68	68		17	136
Nitrogen, N	224		56	448	193	203	193
Chlorine, Cl	318	318	318	318	318	318	318
Sulfur, S	76	76	76	76	76	76	76
Boron, B	3	3	3	3	3	3	3

not likely to prove a detriment to plant growth. However, Hoagland and Snyder (40), working with strawberries, found that some varieties were highly susceptible to injury from sodium salts even tho the sodium was present only in moderate concentration in the solution. The symptom was a marginal burning which sometimes spread until the whole leaf was killed. Considerable diversity of opinion exists among investigators in regard to the most satisfactory concentration of elements for the best growth of plants. Cullinan and others (18), working with peach trees in sand cultures,

found increases in growth of tops and roots when the nitrogen concentration of the nutrient solution was increased, up to 60 ppm. With phosphorus, however, they obtained no increased growth with concentrations above 4 ppm. It now appears from the work of Cullinan and others that the concentration of phosphorus used in the work herein reported was considerably greater than necessary. Nevertheless, the arrangement of cultures gave an opportunity for studying the effects of both deficiencies and excesses, in apples and peaches. Further evidence in this connection was obtained by Batjer and Degman (5) who found that growth in their phosphorus series was approximately uniform in all series which received 4 ppm or more of phosphorus. They found that phosphorous deficiency symptoms occurred only when the phosphorus was completely lacking. In their nitrogen studies with apple trees, they found somewhat less linear growth with the nitrogen concentration at 60 ppm than at 168 ppm. Reduction in the nitrogen supply below 60 ppm reduced the amount of growth almost quantitatively.

Growth Measurements. To determine the growth response of the trees for the different nutrient treatments, measurements of diameter and linear growth were made at weekly intervals thruout the summer. The diameter of the tree trunk was measured at the point where it came thru the cover of the jar and also one foot above the cover. The diameter of the new growth was calipered at a point approximately one inch from the older wood. The leaf and new-growth characteristics were observed frequently and measurements were made to determine the effect of the nutrient treatments on the angle formed between the leaf petioles and the shoots on which they were growing. At the end of the season the trees were removed from the jars, weighed and photographed and the effect of the treatments on root growth was studied. The results of these measurements together with several of the photographs are shown and described in the following pages.

Chemical Analyses. For the determinations of soluble nitrogen and phosphate phosphorus in this study, the first samples were taken from the top third of the twigs which were cut off each tree at the time of potting. Later, the top third of a shoot on each tree was analyzed. All determinations were made colorimetrically from samples taken in duplicate.

Methods of Analysis. In the previous work (88) chemical analyses of twigs were made at weekly intervals to determine the seasonal course of soluble nitrogen and phosphate phosphorus in Winesap apple and Elberta peach trees in the orchard, under various treatments of culture and fertilization. The methods used for the analysis are briefly described in the bulletin just cited and in a journal article (87). They are modifications of the procedures developed by Emmert (26) (27) (28) (29) for his studies with vegetable plants. The determinations of both nitrogen and phosphorus were made upon duplicate samples. In 1926 it was suggested by Loomis (50) that colorimetric procedures for many types of determinations might eventually be found most suitable and he emphasized that any sample worth taking was worth duplicating. Loomis offered suggestions on methods of sampling, preservation of material and certain procedures for chemical determinations. He further stated that in the bulk of physiological analysis the statement of chemical results as percent of the green weight of the tissue appeared to be of the greatest significance. Various other methods have been developed for rapid chemical tests of plants and soil as a means for determining fertilizer needs, and suggestions on their use are offered by Gilbert and Hardin (33) and by Thornton, Conner and Fraser (76).

Further proof in regard to certain procedures that were followed in this work and the conclusions that were drawn has been given by Traub (82) who found that the greatest nitrogen content in twigs occurred in the spring just before growth began. Similar results were obtained in the previous study (88) in apple and peach trees in the orchard. Also in agreement with the work of Traub was the fact that nitrogen was relatively constant and at a low level during the dormant season. Similar results were obtained by Thomas (75) and Piney (59).

In this study and in the previous work, the outer third of twigs was used for analysis because preliminary tests (87) had shown that somewhat higher concentrations of soluble nitrogen occurred in this region than in the median and basal sections. From the results obtained it was thought that the portion of the twig showing the highest analysis of soluble nitrogen would present the most accurate picture of the amount available for metabolic processes. Harvey (35) has pointed out that substances which tend normally

to decrease thruout the growing season, like nitrogen, are always most abundant in the tips of shoots and least abundant in the basal portions and are associated generally with good growth conditions.

It was found in the previous study (88) that, in tissues where no injury had resulted from freezing, an increase in the amount of phosphate phosphorus occurred slightly in advance of the time that new growth began but the amount in twig tissue was soon reduced when leaves had been formed in sufficient number to utilize the phosphorus. In twigs where severe winter injury had occurred (90) the amount of phosphate phosphorus continued to increase notwithstanding that the injury was so severe that no new growth was formed. It has been pointed out by Gardner, Bradford and Hooker (32) that phosphorus is at a maximum in nearly all tissues when buds are swelling and that the chief difference between phosphorus and nitrogen in this respect is that phosphorus reaches a minimum in most tissues in April or May when trees are in bloom while the minimum for nitrogen is not reached until midsummer when active growth has been completed.

Fresh tissue was used for these analyses. A similar procedure has been suggested by Loomis (50). Tottingham (80) has pointed out that both freezing and desiccation modify the nitrogenous constituents in such a manner as to make impossible the true dissection of the nitrogenous fractions. Other investigators have verified these results. It would appear from the conclusions reached by these different workers that a procedure of freezing or drying would change the amount of nitrogen from any one type of nitrogen determination and the amount would differ from that resulting from extraction of fresh tissue.

RESULTS

Growth. After the trees had been set in the jars and new growth had started, the excess buds were removed so that only two shoots were allowed to grow. In practically all cases the most vigorous shoots developed near the distal end of the trunk. The two most vigorous shoots were permitted to grow in order that one of these might be used for chemical analysis after the trees had been growing for several weeks. Weekly records were kept from the beginning, on amount of new growth, trunk diameter increase and characteristics of leaf and petiole development. The results of these measurements are given in the following tables and graphs.

Tables 3, 5 and 7 and figures 1, 2, 3, 4, 9, 10, 11 and 12 give the growth measurements for apples. Tables 4, 6 and 8 and figures 5, 6, 7, 8, 13, 14, 15 and 16 give the growth measurements for peaches. The measurements given for each date in the tables are averages of three weeks, while those shown in the figures are individual weekly measurements.

The results shown in tables 3, 5 and 7 for the growth of the apple trees indicate rather clearly that the response of the Paducah variety under the conditions of this experiment was better, in most cases, than that of Staymared. The exceptions to this statement were the Paducah tree growing in the no-phosphorus culture and the one which received the basal nutrient treatment. Measured by trunk diameter increase, either at the jar cover or one foot above, the no-phosphorus tree failed to respond satisfactorily, altho in percentage green weight gain it exceeded the Staymared. In the basal nutrient treatment, the Paducah tree made less linear growth and also showed a lower percentage green weight gain than the Staymared. In total linear shoot growth, the trees of the two varieties were nearly identical where phosphorus was omitted from the nutrient solution. In comparison with this, the Paducah tree showed a percentage gain in linear growth of 105 percent where the phosphorus was doubled over the amount used in the basal solution, while the Staymared tree showed a percentage gain of only 7.3 for the same treatment. This striking difference is at least suggestive of the phosphorus utilization of these two varieties and would indicate that Paducah trees should respond excellently in soil where the phosphorus content is high. In fact, such a response has occurred with Paducah trees in bluegrass soils where the phosphorus content is unusually high.

No explanation can be offered for some of the other differences in growth response of these two varieties in sand culture except to state that under field conditions trees of the Paducah variety grow more rapidly and come into bearing at a relatively earlier age than Staymared. Possibly some further explanation can be found in the natural growth response of these two kinds under field conditions. The Paducah is a variety of Kentucky origin and is considered to be a seedling of Rome Beauty. It possesses the habit of starting into growth relatively late in the spring and ceases growth fairly early in the summer. It grows vigorously, however, and

Table 3. Stem diameters of apple trees growing in different solutions. Millimeters.
S = Staymared, P = Paducah

Solution	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
Variety	S	P	S	P	S	P	S	P	S	P	S	P	S	P
Measured at jar cover														
May 11	9.5	10.5	10.0	10.0	11.0	9.5	12.0	8.5	9.8		12.0	8.0	10.0	9.5
May 25	9.5	11.0	10.2	10.0	11.2	9.8	12.0	8.9	9.8		12.0	8.2	10.4	9.5
June 15	9.6	11.4	10.5	10.1	11.6	10.2	12.8	9.2	9.8		12.7	8.4	11.2	9.8
July 6	10.0	11.7	dead	10.4	11.8	10.3	13.1	9.8	10.2		12.9	8.8	11.5	10.3
July 27	10.0	11.8		10.9	12.0	10.4	13.9	10.4	10.4		13.0	9.4	11.9	10.9
Aug. 17	10.2	11.8		11.0	12.1	11.0	14.1	10.9	10.4		13.0	10.0	12.0	11.2
Sept. 7	10.4	12.0		11.1	12.3	12.2	14.4	11.3	10.9		13.0	10.6	12.0	11.5
Dec. 21	10.8	12.3		11.3	12.3	13.0	14.8	11.3	11.0		13.0	10.8	12.3	11.8
Gain	1.3	1.8		1.3	1.3	3.5	2.8	2.8	1.2		1.0	2.8	2.3	2.3
Percent	13.7	17.1		13.0	11.8	36.8	23.3	32.9	12.2		10.2	35.0	23.0	24.2
Measured 1 foot above the jar cover														
May 11	9.0	7.5	7.5	7.5	9.0	7.5	9.0	7.0	8.0		8.8	6.0	8.5	7.0
May 25	9.0	7.8	7.8	8.0	9.4	8.0	9.1	7.0	8.0		9.0	6.0	8.8	7.2
June 15	9.0	7.9	8.0	8.0	9.5	8.0	9.4	7.3	8.1		9.3	6.1	9.0	7.4
July 6	9.2	8.1	dead	8.4	9.8	8.2	9.7	8.0	8.7		9.3	6.5	9.4	8.3
July 27	9.3	8.7		8.7	9.9	8.8	10.3	9.6	8.8		9.3	7.3	10.2	8.9
Aug. 17	9.4	9.4		8.9	10.2	9.4	10.7	9.4	9.0		9.4	7.7	10.4	9.6
Sept. 7	9.8	9.5		9.0	10.4	9.9	11.0	9.5	9.0		9.5	7.8	11.0	9.8
Dec. 21	9.8	9.8		9.0	10.5	10.0	11.3	10.0	9.0		10.0	8.0	11.3	10.0
Gain	0.8	2.3		1.5	1.5	2.5	2.3	3.0	1.0		1.2	2.0	2.8	3.0
Percent	8.9	30.7		20.0	16.7	33.3	25.0	42.8	12.5		14.3	33.3	32.9	42.9

Table 4. Stem diameters of peach trees growing in different solutions. Millimeters.

Solution Number	Basal		No nitrogen		1/4 nitrogen		2 nitrogen		No phosphorus		1/4 phosphorus		2 phosphorus	
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Measured at jar cover														
May 11	12.0	10.5	9.0	10.0	9.5	10.3	10.0	9.8	10.8	10.3	11.0	10.0	9.3	9.0
May 25	12.3	10.8	9.3	10.0	9.8	10.9	10.1	10.0	11.2	10.5	11.0	10.0	9.7	9.4
June 15	13.1	10.3	9.5	10.0	10.0	11.1	10.3	10.0	11.3	10.6	11.5	10.1	9.8	9.5
July 6	13.8	10.9	9.8	10.3	10.2	11.4	10.8	10.0	11.3	10.8	12.0	10.8	10.0	9.9
July 27	14.0	11.4	9.8	10.3	10.4	11.5	11.1	10.0	11.5	10.8	12.0	11.0	10.0	10.0
Aug. 17	14.1	11.7	9.8	10.3	10.5	11.6	11.4	10.5	11.6	10.8	12.0	11.0	10.0	10.1
Sept. 7	14.4	11.8	9.8	10.3	10.9	11.9	11.5	10.5	11.9	10.8	12.3	11.0	10.2	10.3
Dec. 21	14.5	11.8	9.8	10.3	11.0	12.0	11.5	10.5	12.0	11.0	12.8	11.3	10.3	10.3
Gain	2.5	1.3	0.8	0.3	1.5	1.7	1.5	0.7	1.2	0.7	1.8	1.3	1.0	1.3
Percent	20.8	9.8	8.9	3.0	15.8	16.5	15.0	7.1	11.1	6.8	16.4	13.0	10.8	14.4
Measured 1 foot above the jar cover														
May 11	8.8	8.0	7.5	8.0	8.0	8.8	8.5	9.0	8.8	8.8	10.0	8.8	8.0	7.8
May 25	8.9	8.3	7.5	8.1	8.1	8.8	8.6	9.0	8.8	8.8	10.0	8.9	8.1	8.3
June 15	9.4	8.7	7.8	8.5	8.4	9.0	8.8	9.1	8.9	9.0	10.1	9.0	8.6	8.7
July 6	9.7	9.1	7.8	8.8	8.7	9.4	9.6	9.7	9.4	9.4	10.9	9.0	8.8	9.0
July 27	10.0	9.5	7.8	8.8	9.2	10.0	9.9	9.9	9.5	9.5	11.0	9.4	9.0	9.3
Aug. 17	10.1	9.8	7.8	8.9	9.8	10.4	10.3	10.0	9.5	9.5	11.0	9.8	9.3	9.3
Sept. 7	10.3	9.9	7.9	9.0	10.4	10.5	10.5	10.2	9.8	9.5	11.0	10.2	9.3	9.4
Dec. 21	10.3	10.0	8.0	9.0	10.8	11.0	10.8	10.3	10.0	9.8	11.5	10.5	9.5	9.5
Gain	1.5	2.0	0.5	1.0	2.8	2.2	2.3	1.3	1.2	1.0	1.5	1.7	1.5	1.7
Percent	17.0	25.0	6.7	12.5	35.0	25.0	27.1	14.4	13.6	11.4	15.0	19.3	18.8	21.8

Table 5. Length of shoot and diameter at the base of the shoot, of apple trees growing in different solutions. Millimeters.
S = Staymared, P = Paducah.

Solution Variety	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
Length of Shoot														
June 8	2	3	2	3	2	2	3	3	2	2	2	3	3	3
June 22	35	35	10	40	20	65	115	130	70	55	70	230	195	235
July 13	90	165	dead	73	95	270	250	270	190	125	166	300	310	293
Aug. 3	177	255		85	230	459	355	363	270	250	179	375	400	455
Aug. 24	325	301		102	345	615	415	454	330	335	181	470	495	535
Sept. 14	438	345		109	515	695	445	508	377	382	185	493	550	595
Dec. 21	519	353		113	540	715	455	513	382	387	189	498	557	722
Average gain	436		113		628		484		385		344		640	
Diameter of shoot at base														
June 8	1.5	1.0	1.5	2.0	1.0	1.5	2.0	2.0	1.3	1.3	1.0	2.0	1.8	2.3
June 22	3.0	3.3	2.8	3.3	2.5	3.3	3.5	3.8	3.0	2.8	2.8	4.0	3.8	4.8
July 13	3.5	5.0	dead	3.8	3.5	4.5	5.0	4.8	4.3	4.0	3.8	4.8	5.0	5.8
Aug. 3	4.3	3.5		4.0	4.8	6.5	5.8	6.0	5.0	5.0	4.0	5.5	5.5	6.0
Aug. 24	4.8	6.0		4.3	6.0	7.8	6.5	6.5	5.5	6.0	4.5	6.3	6.3	6.3
Sept. 14	7.8	6.5		4.3	7.3	9.0	7.0	7.0	6.0	6.3	4.8	6.8	7.0	6.5
Dec. 21	7.0	6.5		4.3	8.5	9.5	8.0	7.8	7.0	6.5	5.5	7.3	7.5	6.8
Average gain	7.4		4.3		9.0		7.9		6.8		6.4		7.2	

Table 6. Length of shoot and diameter at the base of the shoot, of peach trees growing in different solutions. Millimeters.

Solution Number	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Length of shoot														
June 8	3	3	3	3	3	3	3	3	4	3	4	3	3	4
June 22	195	225	115	125	320	290	365	455	530	230	410	305	590	515
July 13	790	825	118	125	670	725	960	720	580	345	1285	505	770	660
Aug. 3	848	865	118	125	695	805	980	740	580	355	1340	550	810	680
Aug. 24	865	890	118	125	705	895	990	745	580	355	1384	592	825	680
Sept. 14	870	890	118	125	705	905	990	745	580	355	1400	610	825	680
Dec. 21	879	910	118	125	705	934	1022	769	580	355	1400	615	825	682
Average gain	895		122		820		896		468		1008		754	
Diameter of shoot at base														
June 8	1.5	1.8	1.3	1.0	1.8	2.0	1.8	1.8	2.3	1.8	2.3	1.8	1.5	1.8
June 22	4.8	4.0	3.3	3.3	4.0	4.5	4.5	3.8	4.8	4.0	5.0	4.5	4.5	4.5
July 13	5.0	5.3	3.3	3.3	5.3	4.8	5.3	4.5	5.3	4.5	5.5	4.5	5.0	5.0
Aug. 3	5.3	5.5	3.3	3.3	6.3	5.8	5.3	4.8	5.3	5.3	6.3	5.5	5.3	5.0
Aug. 24	5.3	5.5	3.3	3.3	6.5	6.0	5.3	4.8	5.3	5.3	6.5	5.5	5.3	5.0
Sept. 14	5.3	5.5	3.3	3.3	6.5	6.0	5.3	4.8	5.3	5.3	6.5	5.5	5.3	5.0
Dec. 21	6.0	6.0	3.3	3.5	6.8	6.0	5.5	4.8	6.0	6.3	7.0	5.8	5.3	5.0
Average gain	6.0		3.4		6.4		5.2		5.7		6.4		5.2	

Table 7. Green weight of the apple trees at the beginning and end of the experiment. Grams.
S = Staymared, P = Paducah

Solution	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
Variety														
April 20	64.0	42.0	51.0	53.0	69.0	42.0	70.0	40.0	52.0	44.0	69.0	30.0	66.0	50.0
Dec. 21	98.3	61.0	dead	66.7	156.9	122.5	139.6	94.1	98.2	87.5	97.0	70.2	123.5	126.2
Gain, grams	34.3	19.0		13.7	87.9	80.5	69.6	54.1	46.2	43.5	28.0	40.2	57.5	76.2
Percent	56.3	45.2		25.9	127.4	191.7	99.4	135.0	88.9	98.9	40.6	134.0	87.1	152.4

Table 8. Green weight of the peach trees at the beginning and end of the experiment. Grams.

Solution	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
Tree	15	16	17	18	19	20	21	22	23	24	25	26	27	28
April 21	64.0	66.0	54.0	55.0	64.0	66.0	66.0	59.0	65.0	62.0	68.0	65.0	52.0	55.0
Dec. 21	101.0	110.5	56.8	59.0	90.5	104.0	112.5	89.0	76.5	69.5	115.5	87.0	78.0	74.5
Gain, grams	37.0	44.5	2.8	4.0	26.5	38.0	46.5	30.0	11.5	7.5	47.5	22.0	26.0	19.5
Percent	57.8	67.4	5.2	7.3	41.4	57.6	70.5	50.9	17.7	12.1	69.9	33.9	50.0	35.5

bears heavily and regularly. The Paducah may be classed distinctly as a fall apple and the Staymared as a winter sort and this may account in some degree for the difference in growth of the two kinds in sand culture.

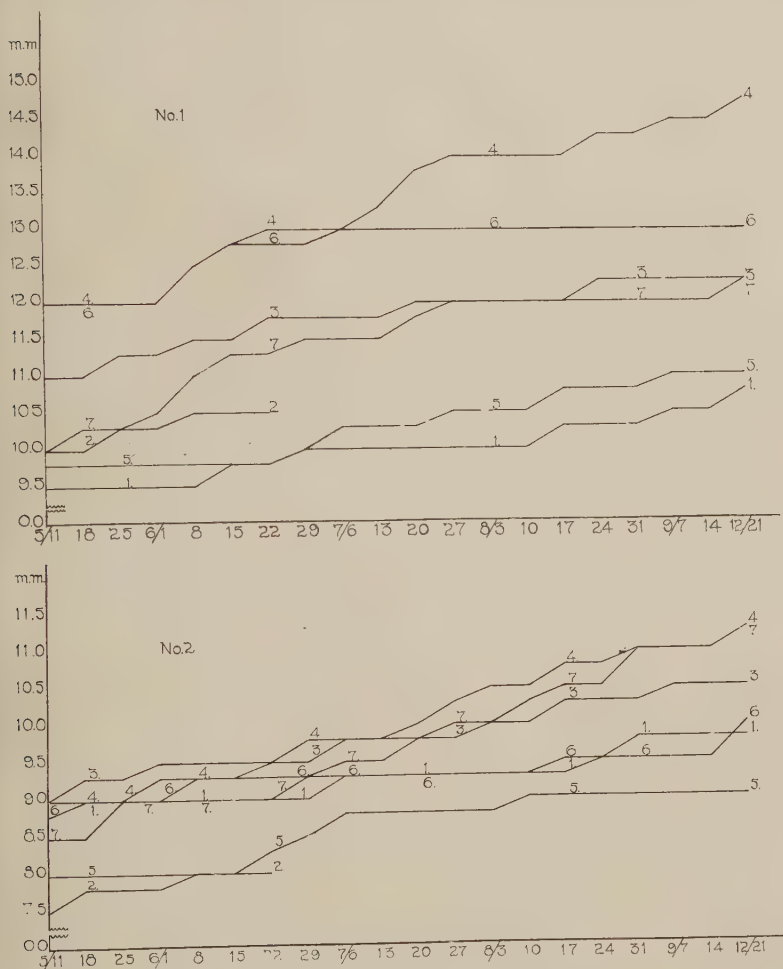


FIGURE 1. Diameter of the Staymared apple trees: No. 1, at the jar cover; No. 2, 1 foot above the jar cover.

In every case except in the basal solution, the response in growth as measured by total linear increase was greater for Paducah than for Staymared. Likewise the percentage increase in weight of

this variety was appreciably greater in all cases except the basal nutrient and no-phosphorus cultures.

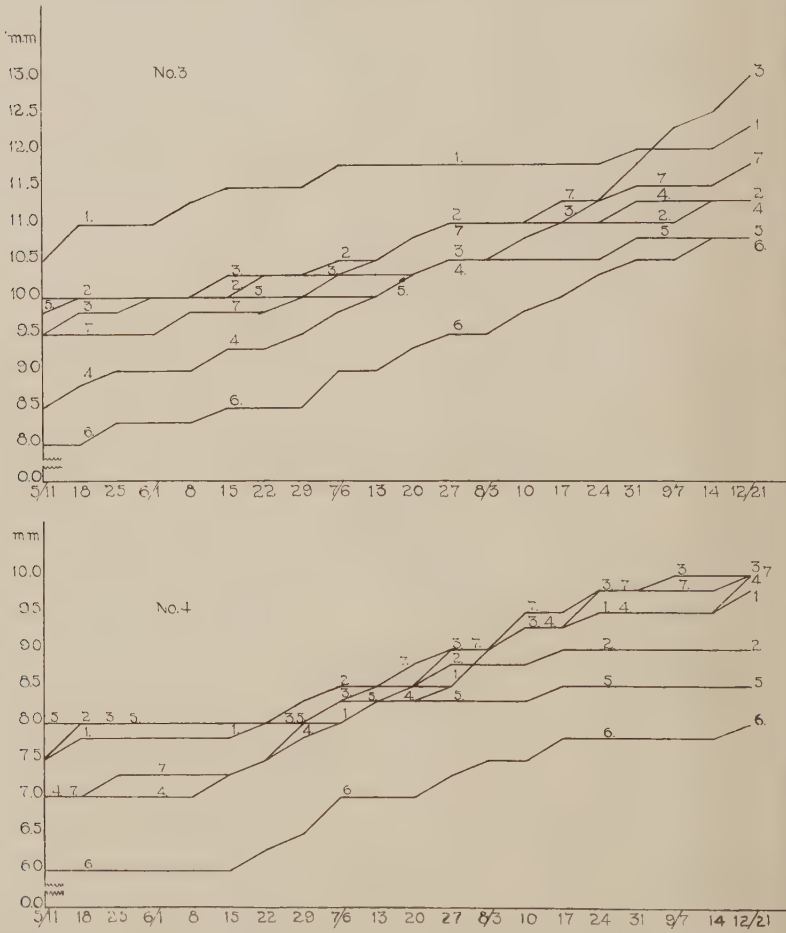


FIGURE 2. Diameter of the Paducah apple trees: No. 3, at the jar cover; No. 4, 1 foot above the jar cover.

The same relationship between the two varieties also held true for the gains in trunk diameter, whether the measurements were made at a point near the crown or one foot above that point. When the diameter measurements of the current growth were compared, however, the greatest gains were not always shown by the Paducah.

The stem diameter measurements for peaches showed quite

consistent increases for all nutrient treatments except the ones where nitrogen was omitted. In this case, relatively small gains were made in either the old or current stem and likewise there were but small amounts of new linear growth.

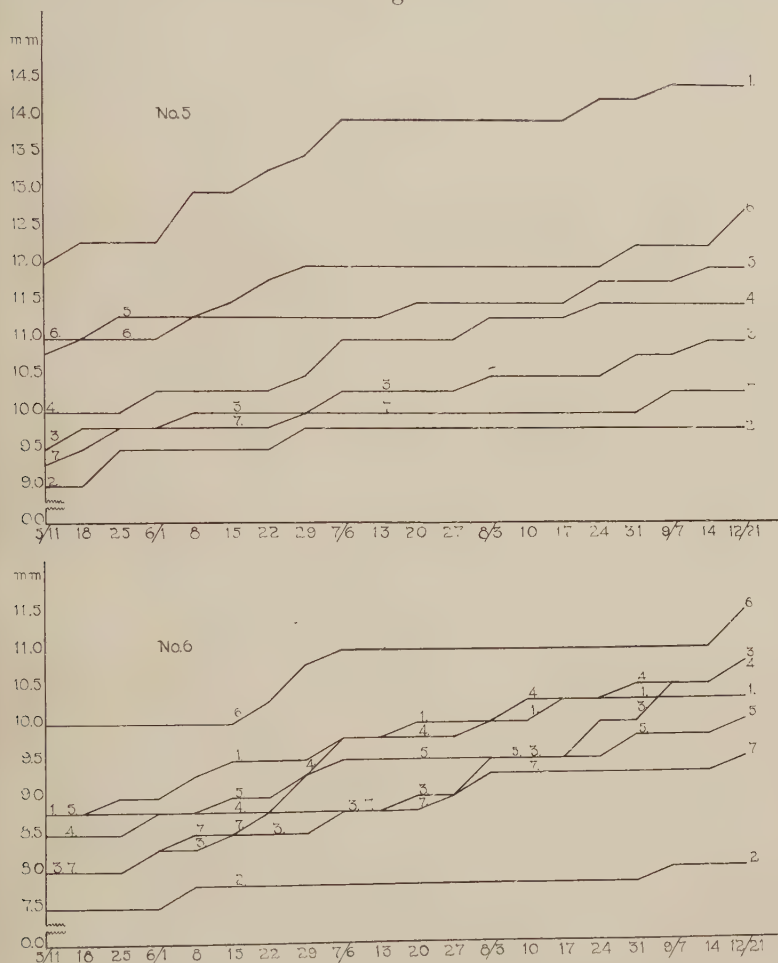


FIGURE 3. Diameter of Elberta peach trees Nos. 15, 17, 19, 21, 23, 25 and 27: No. 5, at the jar cover; No. 6, 1 foot above the jar cover.

In comparing the linear growth and percentage increases in weight of trees of apple and peach, the fact stands out rather clearly that the peach is more sensitive than the apple to a deficiency

in the phosphorus supply. In the apple cultures where phosphorus was omitted the average gain in weight of the two trees was 94 percent while the peaches which received the same treatment gained only 15 percent. The symptoms of phosphorus deficiency, however, were more noticeable on the apple than on the peach trees with the possible exception of the change in the color

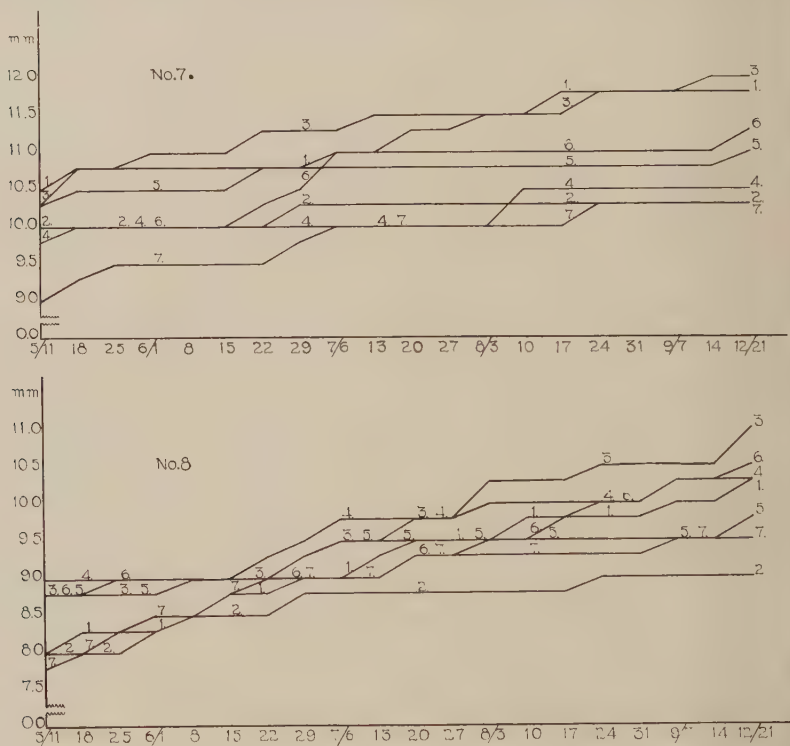


FIGURE 4. Diameter of Elberta peach trees Nos. 16, 18, 20, 22, 24, 26 and 28: No. 7, at the jar cover; No. 8, 1 foot above the jar cover.

of the foliage. In comparison with the peaches, which showed small percentage gains in weight in the absence of a phosphorus supply, the apples grew fairly well, while in the cultures where the phosphorus supply was doubled over the amount used in the basal solution, the apple trees gained considerably more than the peach trees.

In general, the cultures which contained no nitrogen ap-

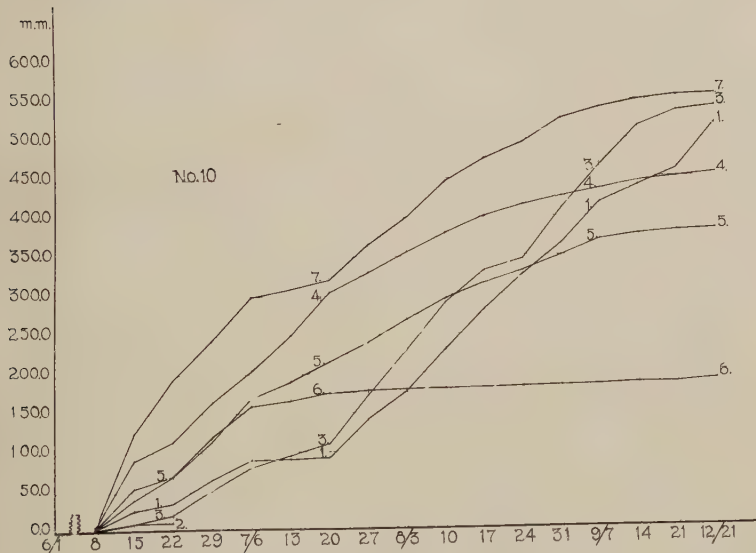
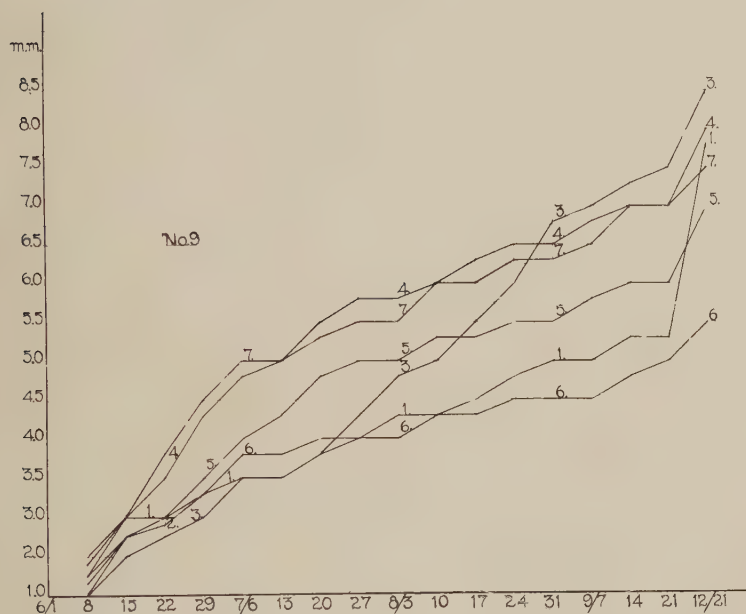


FIGURE 5. Current growth of the Staymared apple trees: No. 9, diameter 1 inch from the main stem; No. 10, length of shoot.

peared more detrimental to the peach trees than to the apples and the effect of this treatment on the peaches was most obvious in the lack of new growth, the yellowish green color of the leaves and the red discoloration of the bark.

In fertilization experiments with peaches under orchard conditions Ashley (3) found that the gains made by trees were in direct proportion to the amount of nitrogen which they received. The results obtained in the experiment herein reported do not agree with the findings of Ashley. For the quantities of nitrogen used in these cultures, there were only slight increases in green weight gain when the nitrogen was increased from 56 to 224 parts per million and even a slightly smaller gain when the nitrogen content of the solution culture was increased to 448 parts per million. It seems quite probable, however, that under field conditions and particularly on light soil with smaller quantities of nitrogen than were employed in these tests, gains made by trees would be in direct proportion to the quantities of nitrogen which they received. The relative quantities of nitrogen used in the first four cultures in this experiment were 0, 1, 4 and 8 while the respective green weight gains for these trees were 0, 1, 1.3 and 1.26. Nearly the same relationship was found for linear growth increases for the trees which received these four treatments with results of 0, 1, 1.1 and 1.1. It appears that nitrogen, when used in excess of 60 parts per million in solution cultures for peaches cannot be expected to give greatly increased results in linear growth increase or in green weight gains. In fact, Cullinan, Scott and Waugh (18) found that when nitrogen was used on peach trees at quantities of 120 and 168 parts per million the gains were not significantly greater than when it was used at 60 parts per million.

When the same comparison is made with the apple trees as is shown above for the peaches, it is found that the heavier nitrogen applications are even less effective in inducing vegetative growth. Comparing the green weight increases in the different nitrogen cultures, the respective gains were 0, 1, .19 and .68, for the relative quantities of nitrogen of 0, 1, 4 and 8, while the linear growth increases for the same trees were 0, 1, .63 and .72. It appears that the heavier applications of nitrogen were detrimental to the growth of the apple trees in sand culture. A point of particular interest with respect to vegetative elongation and the

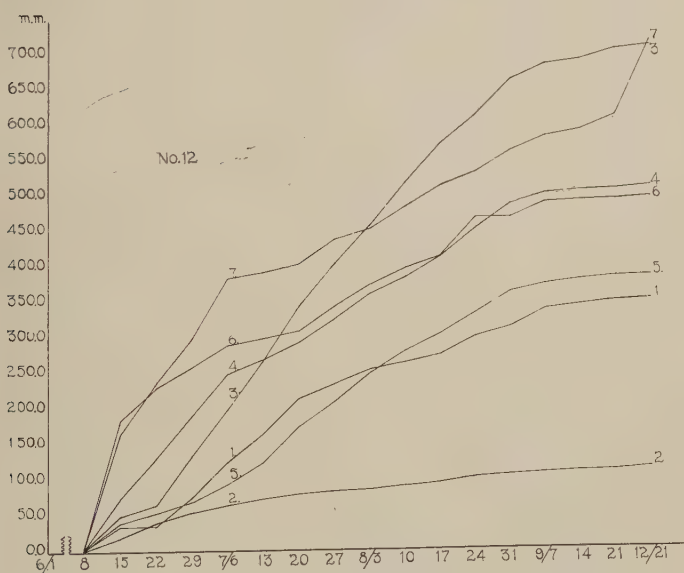
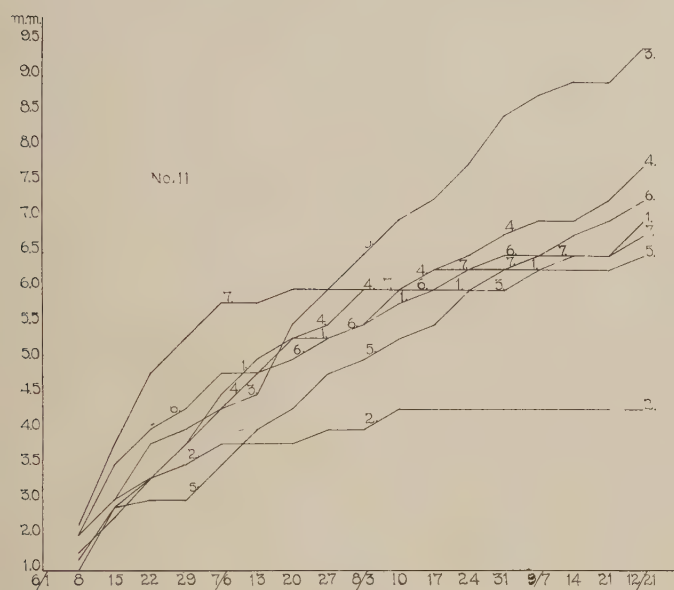


FIGURE 6. Current growth of the Paducah apple trees: No. 11, diameter 1 inch from the main stem; No. 12, length of shoot.

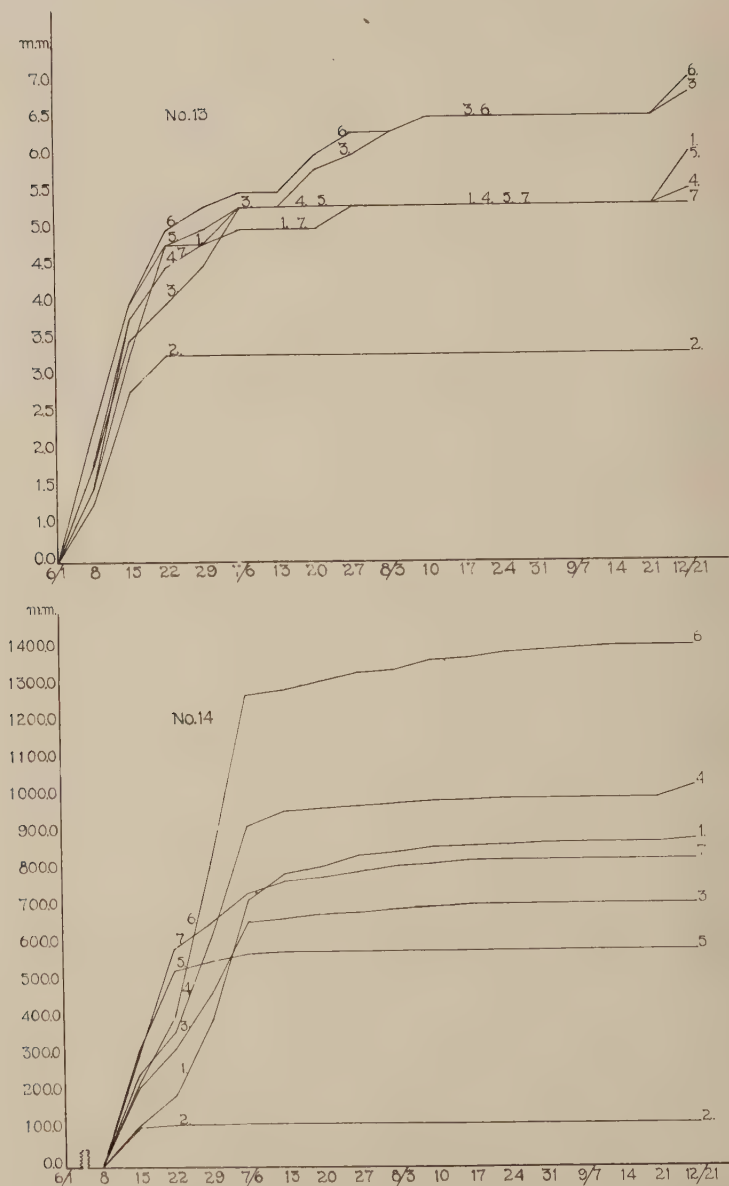


FIGURE 7. Current growth of Elberta peach trees Nos. 15, 17, 19, 21, 23, 25 and 27: No. 13, diameter 1 inch from the main stem; No. 14, length of shoot.

diameter increase of current growth is the fact that shoot growth continued over a considerably longer period on the apples than on the peaches and that the diameter of the current growth continued to increase on the apple trees until late summer. On the peach trees, however, very little increase in shoot diameter occurred after August 3. The shoot growth on peach trees was

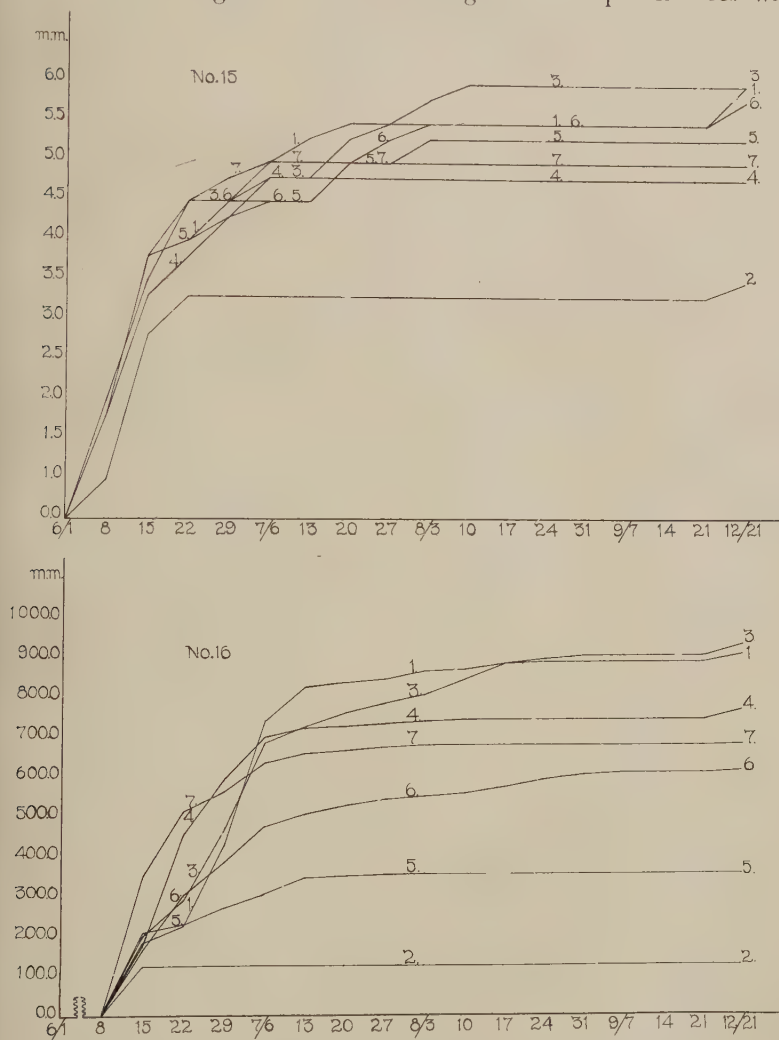


FIGURE 8. Current growth of Elberta peach trees Nos. 16, 18, 20, 22, 24, 26 and 28: No. 15, diameter 1 inch from the main stem; No. 16, length of shoot.

rapid at first but was practically completed within a month or six weeks after the trees were potted. On the apple trees, shoot growth was moderately rapid but continuous until about the first of September. This comparative condition of growth, at least the elongation of shoots, is quite different from that of normal tree growth under field conditions. In general, with trees of moderate vigor, the apple completes its shoot growth in a season several weeks in advance of the time that shoot growth on peaches is terminated.

As stated previously, the roots of all trees were pruned uniformly at the time they were set in the jars. All the fibrous roots were removed and only roots of moderate size were left on the trees. At the end of the experiment the roots were examined and photographed. The results of the examination are recorded in tables 9 and 10. The growth of roots in general, on both apples and peaches, was enhanced in the cultures in which the nitrogen supply was either lacking or limited. These results are in agreement with the findings of Blake, Nightingale and Davidson (11), Weinberger and Cullinan (91) and others. Weinberger and Cullinan found relatively three times as much root growth by weight in proportion to top on trees growing in a solution where no nitrogen was supplied as on trees growing in a complete nutrient solution. The response of trees under these conditions appears to be due to a cessation or marked retardation of cambial activity. In this work, lateral extension in growth of roots was apparently quite rapid but increase in diameter very limited when the nitrogen supply was low. Careful examination of the roots in the cultures where nitrogen was omitted disclosed that much of the cortex had died and sloughed off. In this respect, the roots of these plants differed considerably from those which had grown in the basal nutrient solution. In the latter, the diameter of the roots was larger and the cortical tissue was alive and white. Similar results were reported by Blake, Nightingale, and Davidson (11). With apple or peach trees which received no nitrogen, the effect of this treatment appeared to be much more serious upon top growth than upon root growth.

There was considerable evidence, particularly in the peach trees, that when the nitrogen supply was double the amount used in the basal solution, root growth was seriously retarded. This

same condition has been noted on numerous occasions with plants under field conditions when the soil was extremely rich or when excess quantities of nitrogen-carrying fertilizers had been used. The effect of these conditions on root growth is generally exactly opposite to their effect on vegetative vigor of the parts above ground.

The trees growing in the cultures in which no phosphorus was supplied, formed only fairly good root systems and the treatment appeared more detrimental to the peach than to the apple.

Table 9. Growth of Staymared and Paducah apple tree roots in sand culture.

Nutrient treatment	Tree Number *	Characteristics of the root growth
Basal	1. Fairly good. Laterals slender and quite numerous. Fibrous growth dense.	
	8. Moderately good. Few slender laterals. Fairly good fibrous growth.	
No nitrogen	2. Very little growth. Tree died in the 7th week.	
	9. Extensive root system. Laterals numerous, slender and long. Fibrous growth heavy.	
$\frac{1}{4}$ nitrogen	3. Moderately heavy growth of laterals and fibrous roots.	
	10. Many long, slender roots but comparatively few new fibrous roots. In general fairly good.	
2 nitrogen	4. Good. Laterals long. Fibrous development good but not extensive.	
	11. Moderately good but neither lateral nor fibrous roots numerous.	
No phosphorus	5. Several long, slender laterals. Very little fibrous development.	
	12. Laterals long, slender and not numerous. Fibrous development poor.	
$\frac{1}{4}$ phosphorus	6. Rather poor. Not many laterals. Fibrous growth weak.	
	13. Fairly good. Laterals not numerous. Fibrous growth moderately dense.	
2 phosphorus	7. Very good. Laterals numerous. Fibrous growth heavy.	
	14. Good. Laterals fairly large and long. Fibrous growth moderately heavy.	

*The first tree in each pair is Staymared; the second, Paducah.

Table 10. Growth of Elberta peach tree roots in sand culture.

Nutrient treatment	Tree Number	Characteristics of the root growth
Basal	15.	Good. Good development of laterals. Many fibrous roots.
	16.	Rather poor. Not many laterals. Fibrous growth weak.
No nitrogen	17.	Moderately good but not heavy. Many slender laterals. Fibrous development quite dense.
	18.	Moderately good. Lateral growth fairly extensive. Fibrous growth only fair.
$\frac{1}{4}$ nitrogen	19.	Very extensive root system. Laterals long and numerous. Fibrous growth especially good.
	20.	Roots rather short but numerous. Lateral and fibrous growth good.
2 nitrogen	21.	Very poor. Both lateral and fibrous development small.
	22.	Poor. Laterals few and short. Fibrous growth very limited.
No phosphorus	23.	Rather poor. Laterals limited in size and number. Fibrous growth weak.
	24.	Weak and stunted. Not many laterals. Only a few weak fibrous roots.
$\frac{1}{4}$ phosphorus	25.	Good. Laterals long and numerous. Fibrous development good.
	26.	Fairly good. Laterals numerous, but bunched together. Fibrous growth extensive.
2 phosphorus	27.	Good. Laterals long and numerous. Fibrous development moderately heavy.
	28.	Good. Laterals quite long. Fibrous growth moderately heavy.

Particularly in the apple, the laterals were long and slender and in both kinds of trees the development of fibrous roots was poor. Russell (67) has pointed out that phosphorus is necessary for mitotic cell division and it appeared from the type of growth of roots in these cultures that cambial activity ceased relatively early where the external supply of phosphorus was lacking. Wallace (85) found that phosphorus starvation caused stunting of fruit tree roots and the cause for this appears to be lack of starch transformation.

The starch forms satisfactorily in the absence of phosphorus but is not changed to sugars.

It was pointed out earlier in this discussion that the vegetative growth of peach trees was evidently seriously affected by the lack of an adequate phosphorus supply and now it appears from the studies of root growth in peach trees that this portion of the plant is likewise seriously checked when phosphorus becomes limited. The effect of this treatment on both top and root growth was more detrimental to the peach than to the apple.

When the phosphorus supply was doubled, the roots of all trees made good growth but it seems likely that the amount of phosphorus used in these solutions was more than was actually necessary for adequate and perhaps even for maximum growth.

Photographs of root systems of all trees are shown on page 539.

The tissues of all trees were analyzed for soluble nitrogen and phosphate phosphorus at the time they were set in the jars and again in late summer. The first analyses were made from a portion cut from the top of each shoot which was growth of the previous year. Later in the summer, the upper third of one of the main shoots at the top of each tree was analyzed in the same way. The procedure used for the determinations is described in another publication (87). The results are given in table 11.

In both apples and peaches, the omission of an element from the nutrient solution resulted in only very small quantities of that element being found in the shoot growth of those trees in late summer. This was more particularly true of nitrogen than of phosphorus and was more pronounced in the peach than in the apple.

When the amount of either nitrogen or phosphorus was doubled, over the quantity in the basal solution, it resulted in additional quantities of these nutrients being found in the shoot tissues, but not in amounts proportional to the quantities added.

The findings for soluble nitrogen and phosphate phosphorus in this experiment differ considerably from the results obtained with apple and peach trees under field conditions (88). This was particularly true for nitrogen in the apple trees. In all the cultures except the one where no nitrogen was used, the soluble nitrogen of the apple shoots was much greater in late summer than when the trees were potted and much greater also than for trees in the orchard. A part of this difference may be accounted for by the fact that new

Table 11. Soluble nitrogen and phosphate phosphorus in the stems, April 18, and shoots, August 4, of apple and peach trees growing in sand culture. Parts per million of the fresh tissue.

Treatment	Basal		No nitrogen		¼ nitrogen		2 nitrogen		No phosphorus		¼ phosphorus		2 phosphorus	
Date of test	April 18	Aug. 4	April 18	Aug. 4	April 18	Aug. 4	April 18	Aug. 4	April 18	Aug. 4	April 18	Aug. 4	April 18	Aug. 4
Soluble nitrogen														
Staymared apple	477	1471	375	dead	401	1191	372	1667	393	1136	449	1408	472	1449
Paducah apple	338	1515	325	trace	317	1266	357	1449	310	901	273	1389	345	1316
Average	408	1493	350		359	1229	365	1558	352	1019	361	1399	409	1383
Elberta peach	275	287	146	trace	276	229	216	415	240	465	171	437	349	370
	204	296	130	trace	373	234	408	550	111	516	172	377	306	365
Average	240	292	138	trace	325	232	312	483	176	491	172	407	328	368
Phosphate phosphorus														
Staymared apple	290	387	250	dead	230	392	244	351	274	62	295	254	313	476
Paducah apple	233	370	209	142	247	404	236	410	167	59	160	249	191	437
Average	262	379	230		239	398	240	381	221	61	228	252	252	457
Elberta peach	213	526	182	323	208	444	274	426	196	trace	244	318	244	571
	208	500	210	253	274	476	172	488	248	trace	202	294	240	541
Average	211	513	196	288	241	460	223	457	222	trace	223	306	242	556

shoot growth was analyzed in late summer, while the April 18 results were obtained from growth made the previous season. The nitrogen increase, however, was much greater than could be accounted for by the difference in age of the tissues analyzed. The increase appears to be due largely to the comparatively large quantities of nitrogen used in the nutrient solutions. The same condition, however, did not prevail in the shoots of the peach trees as they were found to contain considerably smaller quantities of soluble nitrogen than the apples and much smaller quantities than were previously found in peach trees under orchard conditions. The comparative characteristics of growth of the apple and peach trees in this experiment, particularly the length of time during which growth continued in the summer, appear to be important factors in explaining the difference in the soluble nitrogen content of the apple and peach shoots. The apple roots apparently remained active and continued to absorb nutrients over a longer time than did the roots of the peach trees. At the same time, shoot growth of the apple trees was steady and continuous over a much longer period than that of the peach. The condition of active growth over a long period and the high accumulation of soluble nitrogen in shoots of the apple, are practically the reverse of these conditions as they occur in orchard trees.

It appears reasonable to conclude that the nutrient treatment stimulated the apple trees to greater activity than is normal for this species but retarded the peach trees in their growth, particularly their season of growth, and in the absorption of nutrient elements by the roots. The other conclusion to which this statement obviously leads, is that a nutrient solution which is suitable to the growth of apple trees in sand culture may give quite different results with peach trees under the same conditions.

The content of phosphate phosphorus in the shoots of both apple and peach trees in the sand cultures was more nearly like that of trees in the orchard and varied much less than nitrogen between the first and last determinations in the season. In general, accumulation of phosphate phosphorus in the peach shoots was greater than in those of the apple, apparently because of early cessation of growth and failure to utilize the nitrogen and, consequently, the phosphorus which were available.

The conditions to which all these trees were subjected, especial-

ly in nutrient supply, were quite different from those which would occur in normal orchard soil. Fresh supplies of certain nutrients were given the trees at frequent intervals and the amounts present were in excess of the probable quantities found in good orchard soil. This was probably more particularly true of nitrogen than of phosphorus. Under average conditions of rainfall the supply of available nitrogen in soil during late summer is moderately high but twig tissues of apple trees at that time usually average only two to four hundred parts per million of soluble nitrogen, on the basis of green weight of tissue (88). Thus, in comparing the content of soluble nitrogen of orchard trees with the findings in this experiment, it is obvious that the nutrient treatments led to some unusual developments in the nutrient content of the shoot growth.

Reaction of the Nutrient Solution. In the preparation of nutrient solutions for use on apple trees in sand culture, Blake, Nightingale and Davidson (11) found that if the pH of the solution was adjusted to 4.2 it gave excellent results. They also found that between the periods of nutrient applications the cultures tended to become less acid, about pH 5.0 to 5.2.

Since the cultures used in this experiment were designed after those of Blake, except for some modifications, it was deemed advisable to adjust the pH to approximately the same degree as that found most suitable by him. After the solutions were prepared and the iron had been added, the pH of each was determined by means of a quinhydrone apparatus which was frequently checked for accuracy against a standard buffer solution of known pH.

Some differences in pH were found in the solutions when they were first prepared and adjustment was made by adding 0.1N H_2SO_4 where needed. The original pH value of each solution, the amount of acid used per liter and the pH value after adjustment are given in the following table.

Solution Number	pH before treatment	Amount of acid per liter (cc)	pH after treatment
1.	4.92	2.03	4.24
2.	5.09	1.20	4.28
3.	4.96	1.30	4.23
4.	5.01	1.25	4.26
5.	5.33	1.35	4.23
6.	5.35	1.13	4.23
7.	4.85	1.12	4.26

Beginning on May 17 and continuing at weekly intervals throughout the summer, pH determinations were made of the nutrient solutions that had been in the sand and in contact with the tree roots. That is, once in each week, when fresh solutions were added to the jars, some of the solution which ran from the drainage tube at the bottom was used for the pH determination. Fifty to 100 cc of solution drained from each jar at the time fresh solution was added. No pH record was made during the first ten days of the test when all trees were treated uniformly with distilled water. Thus, the data for pH determinations on the cultures start on the date when the first nutrient solutions were added to the jars. The results are shown in figures 9 and 10.

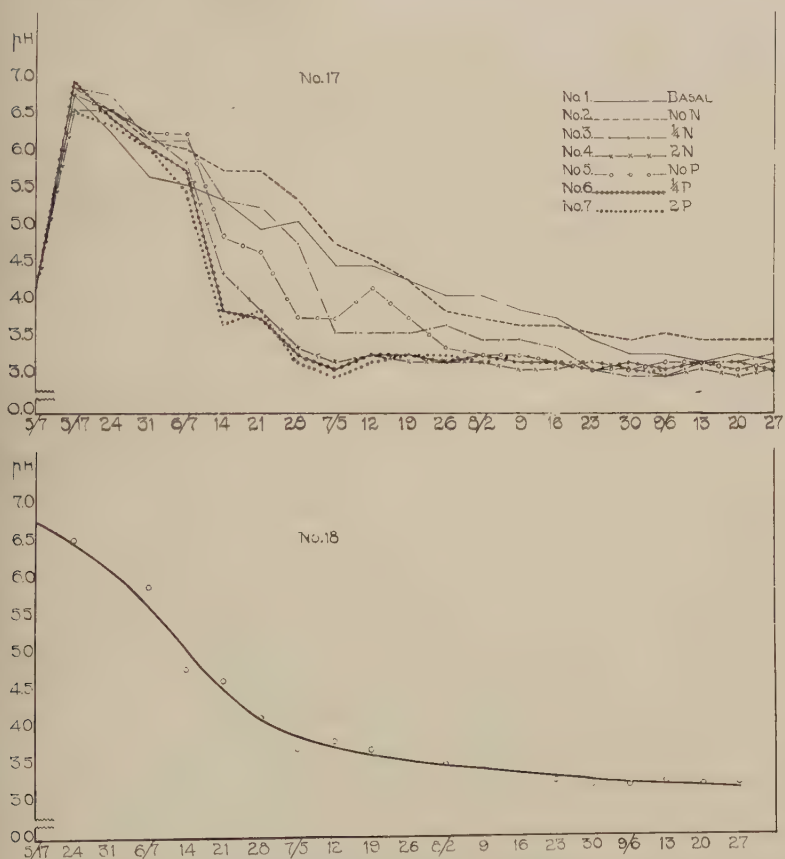


FIGURE 9. pH of the solution which drained from the apple cultures. No. 17, average of the two jars of each kind; No. 18, average of all jars.

The reaction of the nutrient solution was quickly changed in all cultures, from pH 4.2 to nearly 7.0, when it was first added to the sand. Nearly the same reaction change occurred when the sand alone was treated with distilled water, as is shown in figure 11. As the season progressed and the treatments continued, the nutrient solutions

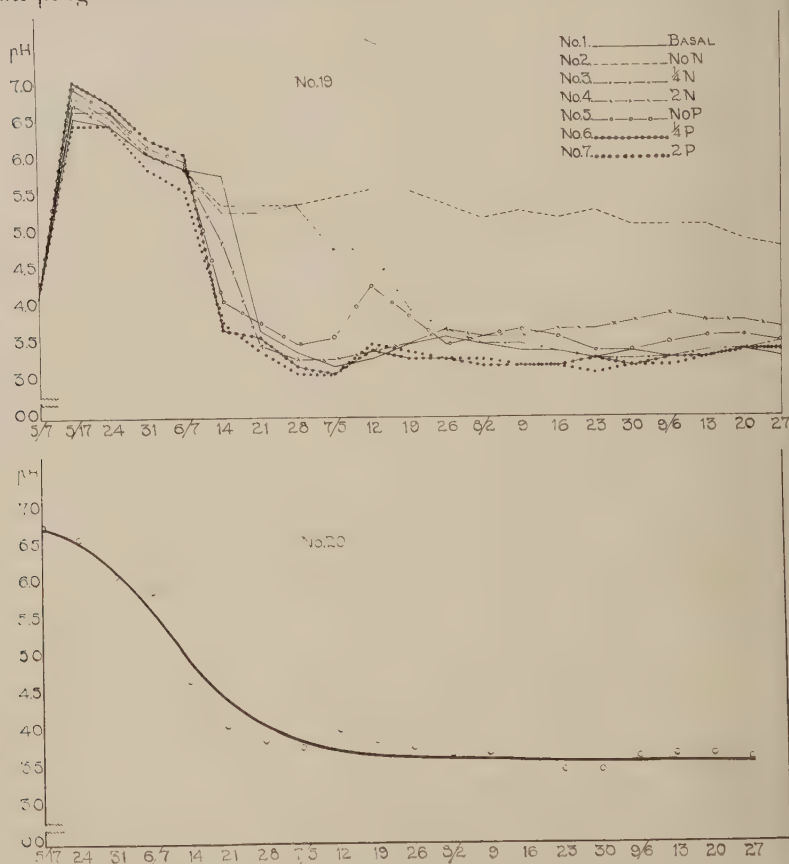


FIGURE 10. pH of the solution which drained from the peach cultures. No. 19, average of the two jars of each culture; No. 20, average of all jars.

which had been in the sand and in contact with the tree roots became more acid. After about seven weeks the solution from all cultures except two was more acid than when it was first added. The exceptions were the basal solution and the one without nitrogen, for the apple trees and the solution without nitrogen and the one with 1/4 N for the peach trees. Other investigators have observed the

tendency of plants to render the nutrient solution more acid. In general, the solutions averaged somewhat more acid for the apple than for the peach cultures. The solution which contained no nitrogen changed less than the others and was more pronounced in this respect in the jars where peaches were growing than in the apple cultures. In fact, in the peach cultures without nitrogen, the average reaction of the solution after passing thru the sand was less acid than at the time of its addition to the jars, during the experiment. The no-nitrogen solution from the apple cultures was less acid than originally, for the first nine weeks. In the experiment with sand in which no trees were growing, after the sudden initial reduction in acidity, the reaction of the solutions gradually became more acid but there were no sudden and rapid reductions in pH later in the test as was observed in both the apple and peach cultures. In the sand alone, the solution which contained no nitrogen was very slightly less acid than the basal solution. In the tree cultures, the reduction in pH must have resulted partly from the action of the sand but probably was caused mainly by the action of the tree roots, such as selective absorption by the roots and excretion of acid substances into the solution.

The greater acidity of the solutions which contained nitrogen appears to be due to a combination of at least two factors. Tree roots have a tendency to increase the acidity of a nutrient solution probably by the excretion of certain materials from their roots and by the carbon dioxide which they give off. Also, absorption of the ammonium ion from ammonium nitrate to a greater extent than the NO_3 ion could cause the formation of nitric acid and a consequent increase in acidity. When the nitrogen was omitted from the solution the reaction was less acid than the others, after being in the sand, even tho adjusted to the same hydrogen-ion concentration as the others when it was prepared. These facts are shown by the No. 2 line in figures 9, 10 and 11.

Following the experiment with the trees in sand culture, a test was arranged to show the effect of the sand alone on the reaction of the nutrient solution. This was done because the results shown in figures 9 and 10 indicate that contact with the sand changed the reaction of the nutrient solutions from about pH 4.2 to 6.5–7.0, when they were first added. In this test four jars of the same lot of unwashed sand were treated with distilled water for a little over two

weeks. Water was added every other day in sufficient quantity so that approximately 100 cc drained from each jar. pH determinations were made each time that water was added. After treatment with distilled water for two weeks, the jars of sand were treated with nutrient solutions which had been adjusted to pH 4.2. Two jars were treated with the basal nutrient solution and two with the solution which contained no nitrogen. Fresh solution was added and pH determined every other day. For the graphic representation, the two jars which received the same treatment were averaged. The results are shown in figure 11. The wavy line indicates the date on which



FIGURE 11. Average pH of distilled water and of two nutrient solutions which drained from jars of sand only.

the nutrient solutions were added. The reaction of both nutrient solutions was changed from pH 4.2 to about pH 6.5, after addition to the sand. A similar change in reaction occurred, from pH 5.7 to pH 8.6, in the distilled water, as shown in the figure.

Deficiency Symptoms. The arrangement of cultures in this experiment permitted the study of deficiency symptoms of both nitrogen and phosphorus with apple and peach trees. It likewise gave an opportunity to study any typical characteristics which developed under conditions where these two elements were used in excess.

Nitrogen Deficiency Symptoms. Characteristics of nitrogen deficiency were evident on the trees in the no-nitrogen jars within a comparatively short time after the nutrient treatments were started. These symptoms were noticeable earlier on the peach than on the

apple and gradually became more pronounced. Most noticeable was the failure of these trees, particularly the peach, to develop a deep green color. The leaves gradually became yellowish-green and brittle, as the season progressed, and were smaller and more slender



FIGURE 12. Some of the peach trees during the experiment. Nos. 15 and 16, basal culture; Nos. 17 and 18, no-nitrogen; Nos. 23 and 24, $\frac{1}{4}$ phosphorus; 27 and 28, 2-phosphorus.

than those on the trees in any of the other treatments. One of the apples failed to make any appreciable new growth and died about the middle of June. The other apple developed fairly well in stem diameter but poorly in linear growth. Both peach trees which received no nitrogen grew poorly from the beginning and failed to

develop satisfactory new growth. The average percentage gain in green weight of these two trees was only about one-tenth that of the two which received the basal nutrient solution. As the season progressed and growth continued, the angle between the leaf petioles and the stem, on the trees which received no nitrogen, became continuously more acute. Similar results were noted by Blake, Nightingale and Davidson (11).

The no-nitrogen trees developed a distinctly red color on the base of the leaf petioles and on the bark of the trunk. This characteristic is not infrequently noted on orchard trees growing under conditions where the nitrogen supply is limited.

Along with the failure of these trees to develop a suitable leaf size and color it was noted that the abscission of the leaves started earlier in the season and that the length of time during which leaves were retained on branches was considerably shorter than for those given other nutrient treatments.

Cullinan, Scott and Waugh (18) have shown that when nitrogen was supplied to peach trees in amounts of 60 parts per million, growth was good and continued until September. In quantities lower than this, growth was reduced and certain deficiency symptoms were noticeable. Altho their trees were somewhat larger when nitrogen was used at 120 and 168 parts per million, the increases were not significantly greater. Similar results were obtained in the test herein reported. The growth and weight increases of the trees were approximately as good when nitrogen was used at 56 as when used at 224 parts per million, and no additional benefit resulted when the nitrogen concentration was 448 parts per million.

The root growth of the trees which received no nitrogen averaged better than that of the trees which received an optimum or a maximum supply. In general, fibrous growth was especially good where nitrogen was omitted from the solution. Other investigators have reported similar results.

Phosphorus Deficiency Symptoms. As previously stated, the omission of phosphorus from the nutrient solution was apparently more detrimental to the peach than to the apple trees. This is shown particularly in table 6, by relative percentage weight increases of the trees in the no-phosphorus series. The percentage gains in weight of the peach trees, when phosphorus was omitted, were nearly as small as for the no-nitrogen treatment.



FIGURE 13. Roots of apple and peach trees at the close of the experiment.

Both apples and peaches in the no-phosphorus series maintained a dark color thruout the summer and became almost a bronze shade late in the season. The color began early in the season as a purplish-red which increased in intensity as the season progressed and the treatment continued. Abscission of foliage from the trees in this treatment occurred later than in those where nitrogen was omitted and was more or less scattered over the branches, whereas on the no-nitrogen trees the leaves from lower branches dropped first and dropping proceeded gradually upward.

In this series the leaves of both apple and peach trees were characteristically long and narrow. A similar type of leaf growth on no-phosphorus trees was noted by Cullinan, Scott and Waugh (18). This type of leaf growth was noted more particularly and was observed earlier in the season on the peach than on the apple trees.

It appears from the work of other investigators that the amount of phosphorus used in these tests, even in the solution containing the minimum amount, was greater than necessary for optimum growth of peach trees. Cullinan, Scott and Waugh (18) found no appreciable gains in peach trees when phosphorus was used in excess of 4 parts per million. Results of this experiment point to the same conclusion, but the apple trees apparently responded in gains where the greatest quantity of phosphorus was added. In general, the root growth on the no-phosphorus trees was poor; laterals were long and slender but not numerous and fibrous development was markedly limited. On the other hand, the apple and peach trees which received the heaviest addition of phosphorus developed good roots with numerous laterals and moderately heavy to heavy fibrous growth.

SUMMARY

(1) Fourteen one-year-old Staymared and Paducah apple trees and the same number of one-year Elberta peach trees were grown in pure sand to which nutrient solutions were added. The nutrient treatment consisted of seven variations; one, basal, complete in its nutrient content and the others differing from it only in amount of nitrogen or phosphorus. This experiment was supplementary to a previous study of nitrogen and phosphorus relationships in orchard trees of apple and peach, analyzed at weekly intervals thruout an entire year. The present study was undertaken primarily for the purpose of observing what symptoms developed when the

trees were subjected to conditions where nitrogen and phosphorus were lacking or were supplied in excess.

(2) Tree growth was measured at weekly intervals thruout the summer by calipering the old stem at two different points and also by caliper measurement of the current growth and a linear measurement of new growth elongation.

(3) Green weight of each tree was determined at the beginning and end of the season and the percentage gain in weight was computed.

(4) Observations and photographs of root growth of each tree are given.

(5) Chemical analyses for soluble nitrogen and phosphate phosphorus were made of the twig and shoot tissues of each tree at the beginning of the experiment and again in late summer. The first analyses were made of the terminal portion of the previous year's growth which contained stored materials, while the late summer analyses were made of the terminal portion of new shoot growth.

(6) At weekly intervals thruout the summer, pH determinations were made of the nutrient solution which drained from each jar at the time fresh solution was added. Check pots which contained no trees were run to show the effect of the sand alone on the reaction of the solutions. These results are shown in graphic form.

(7) When nitrogen was omitted from the nutrient solution growth of the trees was seriously affected. The treatment was more noticeably detrimental to the peach than to the apple and was characterized by yellowish, stunted foliage, early cessation of growth, and premature defoliation.

(8) In general, the response made to any nutrient treatment was somewhat different in the two apple varieties used.

(9) Leaves on trees where nitrogen was omitted assumed an upright position and the leaf petioles formed sharp angles with the branch on which they grew.

(10) Omission of nitrogen from the nutrient solution apparently enhanced the growth of roots. Fibrous root development particularly was good on trees which received this treatment.

(11) Current linear growth was small and slender on trees of the no-nitrogen series and the percentage gains in weight were considerably less than in any other treatment.

(12) When the amount of nitrogen used was double that in the basal solution, the trees increased in weight but not in proportion to the amount of nitrogen added. In fact, with the apples, the best results were obtained when the nitrogen content of the nutrient solution was only one-fourth the amount used in the basal treatment. With the peaches, the basal nutrient application resulted in the greatest average percentage gain in green weight.

(13) In all treatments except the basal solution, the response in total linear increase was greater for Paducah than for Staygreen apple. The same relationship between varieties also held true for the gains in trunk diameter.

(14) With the peach trees, there were consistent trunk diameter increases for all nutrient treatments except the one where nitrogen was omitted. The latter increased only slightly in old stem or current growth diameter, and linear growth was very weak.

(15) Percentage gains in weight of the trees indicated quite clearly that the peach is more sensitive to a deficiency of phosphorus than is the apple. On the other hand, the peach trees did not respond as satisfactorily to heavy phosphorus application as did the apples.

(16) In its effect on gain in green weight, omission of phosphorus from the nutrient solution used on peaches was nearly as serious as omission of nitrogen. Defoliation did not occur as early, however, and the leaves did not develop the chlorotic appearance characteristic of leaves on nitrogen-deficient trees.

(17) Phosphorus-deficiency symptoms were similar in both apple and peach altho somewhat more pronounced in the apple. The leaves were dark green changing to a dark yellowish-green or bronze color late in the season, and were characteristically long and narrow. Leaf abscission occurred later and was more scattered over the branches than in the no-nitrogen trees.

(18) Omission of phosphorus from the nutrient solution seriously affected root growth, particularly the development of fibrous roots. Laterals on these trees were long and slender but few, and fibrous growth was noticeably limited. Doubling the quantity of phosphorus resulted in extensive root development in both apple and peach trees.

(19) Analysis of the new growth, in late summer, for soluble

nitrogen and phosphate phosphorus, showed that the omission of either element from the nutrient solution resulted in a marked reduction of that particular element in the twig tissues. In this respect, the omission of nitrogen gave more pronounced results than the omission of phosphorus and smaller quantities were found in the peach than in the apple.

(20) When the nitrogen or phosphorus supply was doubled, additional quantities of these elements accumulated in the tissues but not in proportion to the amounts added in the nutrient solution.

(21) All nutrient solutions were adjusted to approximately pH 4.2 and when they were first added to the culture jars were changed to a decidedly less acid reaction, about pH 7.0. Further tests in which nutrient solutions were used on jars of sand in which no trees were growing gave nearly the same results. The first solutions which drained from the sand were much less acid than when they were first added, regardless of whether the liquid used was distilled water or nutrient solution. As the leaching continued, on either the tree cultures or sand alone, the solutions gradually became more acid.

(22) Tests of distilled water leaching from the sand and of the sand itself did not disclose the presence of any alkaline material in quantities large enough to account for the decided reduction in hydrogen-ion concentration of the solutions that had drained from the sand. In view of this fact, it seems reasonable to assume that the change in hydrogen-ion concentration from pH 4.2 to about pH 7.0 must have been due largely to selective adsorption by the sand.

(23) In the case of both the tree cultures and the sand alone, all solutions which leached from the jars were more acid after the initial treatment. The most acid reaction developed in the solution which contained the greatest quantity of phosphorus in addition to the usual amount of nitrogen. The least acid reaction was found in the solution which contained no nitrogen. During the last seven weeks of the test, all solutions except the no-nitrogen cultures of the peach trees were more acid than when added to the jars.

(24) The no-nitrogen solution changed much less in pH than the others during the course of the experiment and its concentration of hydrogen ions was considerably less. The reaction of this

solution, even at the conclusion of the test, was less acid in the peach cultures than when added to the jars.

(25) The decidedly acid reaction found during the last few weeks of the experiment in all solutions which contained nitrogen, appears to have been due to a combination of factors. First, probably the continued excretion of certain materials and CO_2 from the roots. Second, the probable hydrolysis of the ammonium nitrate salt and the assimilation of the NH_3 radicle to a greater extent by the roots than that of the NO_3 with the consequent formation of nitric acid. And finally, a continued lowering of the adsorptive ability of the sand as the nutrient treatments continued.

LITERATURE CITED

1. Alexander, L. J., Morris, V. H., and Young, H. C. 1939. Growing Plants in Nutrient Solution. Ohio Agr. Exp. Sta. Sp. Cir. 56.
2. Armstrong, W. D., Stuckey, H. P., and Cochran, H. L. 1935. Nitrogen Fertilizer Studies with the Elberta Peach. Proc. Amer. Soc. Hort. Sci. 33: 268. Abs.
3. Ashley, T. E., 1931. Some Vegetative Responses of the Peach to Applications of Nitrate of Soda. Proc. Amer. Soc. Hort. Sci. 28: 28-33.
4. Baker, Clarence E., 1936. The Relation of Nitrogen and Soil Moisture to Growth and Fruitfulness of Apple Trees under Different Systems of Soil Management. Purdue Agr. Exp. Sta. Bul. 414.
5. Batjer, L. P., and Degman, E. S. 1937. The Effect of Varying Amounts of Nitrogen, Potassium and Phosphorus on the Growth and Assimilation of Young Apple Trees. Proc. Amer. Soc. Hort. Sci. 35: 255.
6. Batjer, L. P., and Sudds, R. H. 1937. The Effect of Nitrate of Soda and Sulfate of Ammonia on Soil Reaction and Root Growth of Apple Trees. Proc. Amer. Soc. Hort. Sci. 35: 279-282.
7. Baudisch, Oskar 1911. Ueber Nitrat-und Nitrit-Assimilation. Ber. 44: 1009.
8. Baudisch, Oskar, and Maeyer, Erwin 1913. Ueber Nitrat-und Nitrit-Assimilation. V. Ber. 46: 115-125.
9. Blake, M. A., and Davidson, O. W. 1934. The New Jersey Standard for Judging the Growth Status of the Delicious Apple. N. J. Agr. Exp. Sta. Bul. 559.
10. Blake, M. A., Nightingale, G. T., and Davidson, O. W. 1936. Responses of Young Apple Trees to Nutrient Deficiencies. Proc. Amer. Soc. Hort. Sci. 34: 137-138.
11. Blake, M. A., Nightingale, G. T., and Davidson, O. W. 1937. Nutrition of Apple Trees. N.J. Agr. Exp. Sta. Bul. 626.
12. Chandler, W. H. 1925. Fruit Growing. Houghton Mifflin Co. Cambridge, Mass.
13. Chapman, H. D., and Liebig, G. F. Jr. 1938. Adaptation and Use of Automatically Operated Sand-Culture Equipment. Jour. Agr. Res. 56: No. 1.

14. Childers, N. F., and Cowart, F. F. 1935. The Photosynthesis, Transpiration, and Stomata of Apple Leaves as Affected by Certain Nutrient Deficiencies. *Proc. Amer. Soc. Hort. Sci.* 33: 160-163.
15. Clark, H. E., and Shive, J. W. 1934. The Influence of the pH of a Culture Solution on the Assimilation of Ammonium and Nitrate Nitrogen by the Tomato Plant. *Soil Sci.* 37: 459-476.
16. Combes, R. 1926. Etude de la Migration Automnal des Substances Azotees chez le chene par l'analyse de Plantes Entieres. *Compt. Rend. Acad. Sci. (Paris)* 182: 16: 984-987.
17. Cooper, J. R., and Wiggans, C. B. 1929. A Study of the Effect of Commercial Fertilizers on the Performance of Peach Trees. *Ark. Agr. Exp. Sta. Bul.* 239.
18. Cullinan, F. P., Scott, D. H., and Waugh, J. G. 1938. The Effect of Varying Amounts of Nitrogen, Potassium and Phosphorus on the Growth of Young Peach Trees. *Proc. Amer. Soc. Hort. Sci.* 36: 61-68.
19. Curtis, O. F. 1935. *The Translocation of Solutes in Plants.* McGraw-Hill Co.
20. ———— 1936. The Translocation of Mineral Elements in Plants. *Proc. Amer. Soc. Hort. Sci.* 34: 222-223.
21. Davidson, O. W., and Blake, M. A. 1936 (Abstract). Responses of Young Peach Trees to Nutrient Deficiencies. *Proc. Amer. Soc. Hort. Sci.* 34: 247-248.
22. ———— 1937. Nutrient Deficiency and Nutrient Balance with the Peach. *Proc. Amer. Soc. Hort. Sci.* 35: 339-346.
23. Davidson, O. W. 1938. (Abstract.) Symptoms of Malnutrition in the Peach Resulting from Various Combinations of Nutrient Deficiencies. *Proc. Amer. Soc. Hort. Sci.* 36: 87-88.
24. Davis, A. R., and Hoagland, D. R. 1928. An Apparatus for the Growth of Plants in a Controlled Environment. *Plant Physiology* 3: 277-292.
25. Eaton, F. M. 1935. Automatically Operated Sand-Culture Equipment. *Jour. Agr. Res.* 53: No. 6.
26. Emmert, E. M. 1930. A Method for the Rapid Determination of Phosphorus in Fresh Plant Tissue. *Plant Physiology* 3: 413-417.
27. ———— 1934. Tests for Phosphate, Nitrate, and Soluble Nitrogen in Conducting Tissue of Tomato and Lettuce Plants, as Indicators of Availability and Yield. *Ky. Agr. Exp. Sta. Circ.* 43.
28. ———— 1935. Method for Quickly Determining Nitrogen in Plants and Soluble Nitrogen as a Measure of the Nitrogen Available for Anabolic Processes. *Plant Phys.* 10: 355-364.
29. ———— 1935. New Methods for the Determinations of the Availability of Nitrogen and Phosphorus to Plants. *Jour. Amer. Soc. Agron.* 27: No. 1.
30. ———— 1931. The effect of Soil Reaction on the Growth of Tomatoes and Lettuce and on the Nitrogen, Phosphorus and Manganese Content of the Soil and Plant. *Ky. Agr. Exp. Sta. Res. Bul.* 314
31. Fisher, P. L. 1935. Responses of the Tomato in Solution Cultures with Deficiencies and Excesses of Certain Essential Elements. *Md. Agr. Exp. Sta. Bul.* 375: 283-298.

32. Gardner, V. R., Bradford, F. C., and Hooker, H. D. 1939. *The Fundamentals of Fruit Production*. McGraw-Hill Co.
33. Gilbert, B. E., and Hardin, L. J. 1927. The Current Mineral Nutrient Content of the Plant Solution as a Possible Means of Chemical Control of Optimum Fertilization. *Jour. Agr. Res.* 35, No. 2.
34. Godlewski, E. 1911. Sur le Role des Nitrates dans l'alimentation des Plantes. *Rev. Sci. (Paris)* 49, II 6; 178.
35. Harvey, E. M. 1923. A Study of Growth in Summer Shoots of the Apple with Special Consideration of the Role of Carbohydrates and Nitrogen. *Ore. Agr. Exp. Sta. Bul.* 200.
36. Heinicke, A. J. 1937. Cultural Conditions Influencing the Manufacture of Carbohydrates by Apple Leaves. *Proc. N. Y. State Hort. Soc.* 149-160.
37. Hill, H., and Grant, E. P. 1935. The Growth of Turnips in Artificial Cultures. *Cent. Exp. Fm. Ottawa, Can. Sci. Agr.* 15: 9.
38. Hoagland, D. R. 1923. The Effect of the Plant on the Reaction of the Culture Solution. *Cal. Agr. Exp. Sta. Tech. Paper*, No. 12.
39. Hoagland, D. R., and Chandler, W. H. 1932. Some Effects of Deficiencies of Phosphate and Potassium on the Growth and Composition of Fruit Trees under Controlled Conditions. *Proc. Amer. Soc. Hort. Sci.* 29: 267-271.
40. Hoagland, D. R., and Snyder, W. C. 1933. Nutrition of Strawberry Plants under Controlled Conditions. (a) Effect of Deficiencies of Boron and Certain other Elements: (b) Susceptibility to Injury from Sodium Salts. *Proc. Amer. Soc. Hort. Sci.* 30: 288-294.
41. Hoagland, D. R., and Arnon, D. I. 1938. The Water-Culture Method for Growing Plants Without Soil. *Cal. Agr. Exp. Sta. Circ.* 347.
42. Hooker, H. D. Jr. 1922. Certain Responses of Apple Trees to Nitrogen Applications of Different Kinds and at Different Seasons. *Mo. Agr. Exp. Sta. Res. Bul.* 50.
43. Howlett, F. S. 1926. The Nitrogen and Carbohydrate Composition of the Developing Flowers and Young Fruits of the Apple. *Cornell Agr. Exp. Sta. Memoir* 99.
44. Kraus, E. J., and Kraybill, H. R. 1922. Vegetation and Reproduction with Special Reference to the Tomato. *Ore. Agr. Exp. Sta. Bul.* 149.
45. Lagasse, F. S. 1926. The Effect of Fertilizers on the Chemical Constituents of Fruit Spurs. *Proc. Amer. Soc. Hort. Sci. Rept.*
46. Laurent, J. 1904. Recherches sur la Nutrition Carbone des Plantes vertes a l'aide de Matieres Organiques. *Rev. Gen. Bot.* 16: 231-241.
47. Leclerc, Du Sablon 1904. Recherches Physiologiques sur les Matieres du Reserve des Arbres. *Rev. Gen. Bot.* 16: 386-401.
48. Lilleland, O. 1932. Experiments in K and P Deficiencies with Fruit Trees in the Field. *Proc. Amer. Soc. Hort. Sci.* 29: 272-276.
49. ————— 1935. Phosphate Response with Closely Planted One-year-old Fruit Trees. *Proc. Amer. Soc. Hort. Sci.* 33: 114-119.
50. Loomis, W. E. 1926. Methods for the Analysis of Horticultural Plants. *Proc. Amer. Soc. Hort. Sci.* 23: 285-293.

51. ————. 1934. The Translocation of Nitrogen in Woody Plants. *Proc. Amer. Soc. Hort. Sci.* 32: 61-64.
52. Magness, J. R., and Regeimbal, L. O. 1938. The Nitrogen Requirement of the Apple. *Proc. Amer. Soc. Hort. Sci.* 36: 51-55.
53. Marsh, R. P., and Shive, J. W. 1925. Adjustment of Iron Supply to Requirements of Soy Beans in Solution Culture. *Bot. Gaz.* 79, 1.
54. Martin, J. P., and Carpenter, C. W. 1939. The Growth of Plants in Water and Sand Cultures. *The Hawaiian Planters Record*. Vol. XLIII, No. 2, Sec. Quart.
55. McCall, A. G. 1916. A Method for the Renewal of Plant Nutrients in Sand Culture. *Ohio Jour. of Sci.* 15: 3, 101-103.
56. Murneek, A. E., and Logan, J. C. 1932. Autumnal Migration of Nitrogen and Carbohydrates in the Apple Tree. *Mo. Agr. Exp. Sta. Res. Bul.* 171.
57. Murneek, A. E. 1936. Fertilizing Fruit Trees with Nitrogen. *Mo. Agr. Exp. Sta. Bul.* 363.
58. Nightingale, G. T. 1927. The Chemical Composition of Plants in Relation to Photoperiodic Changes. *Wis. Agr. Exp. Sta. Res. Bul.* 74.
59. Piney, M. 1929. Variations Qualitatives et Quantatives des Substances Azotees chez une Plante Ligneuse au debut de la Periode de Vegetation. *Rev. Gen. Bot.* 41: 67-93.
60. Pirschle, Karl 1931. Nitrate und Ammonsalze als Stickstoffquellen fuer Hoehere Pflanzen bei Konstanter Wasserstoffionenkonzentration. *Ztschr. Wiss. Biol. Abt. E. Planta.* 14: 583-676.
61. Proebsting, E. L., and Kinman, C. F. 1933. Orchard Trials of Nitrogen and Phosphorus. *Proc. Amer. Soc. Hort. Sci.* 30: 426-430.
62. Rawl, E. H. 1935. Peach Tree Abnormalities Developing from Applications of Nitrogen Fertilizer Alone. *Proc. Amer. Soc. Hort. Sci.* 33: 293-298.
63. Remy, Th. 1913. Stickstoffversorgung und Blütenansatz der Obstbaume. *Deut. Landw. Gesell. Mitteil.* 29: 416-427.
64. Ripple, A. 1921. Die Frage der Eiweisswanderung beim Herbstlichen Vergelben der Laubblaetter. *Biol. Zentralbl.* 41: 508-523.
65. Robbins, W. R. 1928. The Possibilities of Sand Culture for Research and Commercial Work in Horticulture. *Proc. Amer. Soc. Hort. Sci.* 25: 368-370.
66. Roberts, R. H. 1921. Nitrogen Reserves in Apple Trees. *Proc. Amer. Soc. Hort. Sci.* 18: 143-145.
67. Russell, E. J. 1927. Soil Conditions and Plant Growth. Longmans, Green and Co. Ltd. N. Y.
68. Scofield, C. S. 1927. The Effect of Absorption by Plants on the Concentration of the Soil Solution. *Jour. Agr. Res.* 35, No. 8.
69. Scott, L. E. 1938. Response of Peach Trees to Potassium and Phosphorus Fertilizers in the Sandhill Area of the Southeast. *Proc. Amer. Soc. Hort. Sci.* 36: 56-60.
70. Shive, J. W., and Robbins, W. R. 1939. Methods of Growing Plants in Solution and Sand Cultures. *N.J. Agr. Exp. Sta. Bul.* 636.

71. Sullivan, J. T., and Cullinan, F. P. 1931. Carbohydrate and Nitrogen Relationships in Apple Shoots as Influenced by Soil Management. *Proc. Amer. Soc. Hort. Sci.* 28: 519-525.
72. Sullivan, J. T., and Baker, C. E. 1936. Effect of Cultural Treatments on the Growth and Nitrogen Content of Apple Shoots and Spurs. *Proc. Amer. Soc. Hort. Sci.* 34: 149-154.
73. Thomas, W. 1927. Nitrogen Metabolism in *Pyrus malus*. III The Partition of Nitrogen in the Leaves, One and Two Year Branch Growth and Non-bearing Spurs Throughout a Year's Cycle. *Plant Phys.* 2:2: 109-137.
74. ———— 1932. Utilization of Nitrogen, Phosphorus and Potassium by *Pyrus malus* Subjected to Differential Treatment with Nutrient Salts. *Proc. Amer. Soc. Hort. Sci.* 29: 239 Abs.
75. ———— 1933. Absorption, Utilization and Recovery of Nitrogen, Phosphorus and Potassium by Apple Trees Grown in Cylinders and Subjected to Differential Treatment with Nutrient Salts. *Jour. Agr. Res.* 47: 565-582.
76. Thornton, S. F., Connor, S. D., and Fraser, R. R. 1936. The use of Rapid Chemical Tests on Soils and Plants as Aids in Determining Fertilizer Needs. *Purdue Agr. Exp. Sta. Circ.* No. 204.
77. Tiedjens, V. A., and Robbins, W. R. 1931. The Use of Ammonia and Nitrate Nitrogen by Certain Crop Plants. *N. J. Agr. Exp. Sta. Bul.* 526.
78. Tiedjens, V. A. 1932. Some Observations on the Assimilation of Ammonium and Nitrate Nitrogen in Some Horticultural Plants. *Proc. Amer. Soc. Hort. Sci.* 29: 253-254.
79. Tiedjens, V. A., and Blake, M. A. 1932. Factors Affecting the Use of Nitrate and Ammonium Nitrogen by Apple Trees. *N. J. Agr. Exp. Sta. Bul.* 547.
80. Tottingham, W. E., Schultz, E. R., and Lepkovsky, S. 1924. The Extraction of Nitrogenous Constituents from Plant Cells. *Jour. Amer. Chem. Soc.* XLVI; 203-209.
81. Trelease, S. F., and Trelease, H. M. 1935. Changes in Hydrogen-ion Concentration of Culture Solution Containing Nitrate and Ammonium Nitrogen. *Amer. Jour. Bot.* 22: 520-542.
82. Traub, H. P. 1927. Regional and Seasonal Distribution of Moisture, Carbohydrates, Nitrogen and Ash in 2-3 Year Portions of Apple Twigs. *Minn. Agr. Exp. Sta. Tech. Bul.* 53.
83. Turner, W. I., and Henry, V. M. 1939. Growing Plants in Nutrient Solutions. *J. Wiley and Sons.* N. Y.
84. VanSlyke, L. L., Taylor, O. M., and Andrews, W. H. 1905. Plant Food Constituents Used by Bearing Fruit Trees. N.-Y. (Geneva) *Agr. Exp. Sta. Bul.* 265.
85. Wallace, T. 1930. Some Effects of Deficiencies of Essential Elements on Fruit Trees. *Ann. Appl. Biol.* 17: 649-657.
86. Waltman, C. S. 1931. Effect of Hydrogen-ion Concentration on the Growth of Strawberries in Sand and in Soil. *Ky. Agr. Exp. Sta. Res. Bul.* 321.
87. ———— 1936. A Rapid Method for Determining Soluble Nitrogen and Phosphate Phosphorus in Woody Tissue. *Proc. Amer. Soc. Hort. Sci.* 34: 130-132.

88. ————— 1936. The Seasonal Course of Soluble Nitrogen and Phosphate Phosphorus in the Shoot Growth of Winesap Apple and Elberta Peach. Ky. Agr. Exp. Sta. Bul. 367.
89. ————— 1937. The Effect of Fall Nitrogen Fertilization on the Soluble Nitrogen and Phosphate Phosphorus Content of Dormant Peach Twigs. Proc. Amer. Soc. Hort. Sci. 35: 273-278.
90. ————— 1938. Phosphate Phosphorus and Soluble Nitrogen Changes in Living and Winter Killed Peach Twigs. Proc. Amer. Soc. Hort. Sci. 36: 181-184.
91. Weinberger, J. H., and Cullinan, F. P. 1936. Symptoms of Some Mineral Deficiencies in One-year Elberta Peach Trees. Proc. Amer. Soc. Hort. Sci. 34: 249-254.
92. Williams, C. F. 1931. Season Variations in Nitrogen Concentration in Twigs of Peach Trees under Sandhill Conditions. Proc. Amer. Soc. Hort. Sci. 28: 39-44.

SUBJECT INDEX

	Page
Apple and peach trees, effect of nitrogen and phosphorus on the growth of in sand culture	489
nitrogen deficiency in	497, 536
phosphorus deficiency in	499, 538
response to nitrogen	490
response to phosphorus	496
Blackfire of tobacco, and soil fertility	29
Bordeaux treatment of beds helps control of	24
description of	19
manure helps to prevent	29
Burley tobacco, cost of curing with artificial heat	335
effect of temperature and humidity on quality of	355
experiments in curing	359
firing practices	347
seasonal movements in prices and sales of	401
Distillery slop for hogs	387
Effect of nitrogen and phosphorus on the growth of apple and peach trees in sand culture	489
Hogs, distillery slop for	387
Manure helps prevent blackfire of tobacco	29
Maybeetles, distribution of	77
habits of	97
life cycle of	96
pupation of	131
species in Kentucky	75
the egg stage	118
the larval stage	119
Nitrogen, effect of, on growth of apple and peach trees in sand culture ..	489
Peach and apple trees, effect of nitrogen and phosphorus on the growth of, in sand culture	489

Phosphorus, effect of, on growth of apple and peach trees in sand culture	489
Prices and sales of Burley tobacco, seasonal movements in	401
Reproductive efficiency of dairy cattle, analysis of	163
Robertson county, farm income and family living in	307
Sand cultures, chemical analyses of trees in	508, 530
effect of sand on the pH	536
experimental procedure with	501
growth measurements of trees in	508
nutrient solutions for	502
reaction of the nutrient solution in	532
root growth of trees in	527, 528
Salmonella typhi-murium, biological characteristics of	64, 65
biological characteristics of IV variants	66
significance of types of	43
zoological distribution of ammonia - weak types	70
zoological distribution of biochemical types	67
zoological distribution of serological types .	68
zoological distribution of biological types among IV variants	69
Soil of the dark-tobacco area	32
Tobacco, control of blackfire of	19
injury to by wireworms	3
White grubs, key to in Kentucky	126
methods of studying	143
natural enemies of	141
other than phyllophaga	136
Wireworms, injury to tobacco plants by	3
control of on tobacco	7
populations in relation to injury	6
species which injure tobacco plants	4

AUTHOR INDEX

	Page
Bondurant, John H., and Max M. Tharp, Bulletin 405 by	307
Brown, A. J., and Dana G. Card, Bulletin 403 by	191
Bruner, D. W., and P. R. Edwards, Bulletin 400 by	43
————— Bulletin 404 by	291
Byers, Geo. B., Bulletin 406 by	335
Card, Dana G., and A. J. Brown, Bulletin 403 by	191
————— and Carl M. Clark, Bulletin 409 by	403
Clark, Carl M., and Dana G. Card, Bulletin 409 by	403
Dimock, W. W., and others, Bulletin 402 by	161
Edwards, P. R., and D. W. Bruner, Bulletin 400 by	43
————— Bulletin 404 by	291
Ely, Fordyce, and others, Bulletin 402 by	161
Hull, F. E., and others, Bulletin 402 by	161
Jeffrey, R. N., Bulletin 407 by	355
Jewett, H. H., Bulletin 398 by	3
Johnson, E. M., and W. D. Valleau, Bulletin 399 by	19
Karraker, P. E., and W. S. Ligon, Circular 51 by	—
Ligon, W. S., and P. E. Karraker, Circular 51 by	—
Morrison, H. B., and others, Bulletin 402 by	161
Ritcher, P. O., Bulletin 401 by	73
Tharp, Max M., and John H. Bondurant, Bulletin 405 by	307
Valleau, W. D., and E. M. Johnson, Bulletin 399 by	19
Waltman, C. S., Bulletin 410 by	489
Wilford, E. J., Bulletin 408 by	387

KENTUCKY
AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF KENTUCKY
THOMAS P. COOPER, Director

A KEY TO KENTUCKY SOILS

By P. E. KARRAKER¹ and W. S. LIGON²

INTRODUCTION

Soils differ greatly. In Kentucky, these differences are due mainly to differences in (1) parent material and (2) topographic position and consequent degree of internal drainage during the soil-forming process.

Percolation of water thru soil or soil materials removes soluble matter and fine particles from the surface layer. These fine particles and that part of the soluble matter which precipitates, lodge at a lower depth to form a heavier under layer and thus different layers, or horizons, slowly develop. The surface soil, or leached layer, is designated as the A horizon; the subsoil, or layer of accumulation, the B horizon; and the original undifferentiated parent material, the C horizon. Additional horizons develop under certain conditions, such as the presence of a high water table during soil formation. The soil profile is a vertical section thru a soil comprising all the horizons which may occur. The thickness and depth of the various horizons, together with the physical and chemical properties characteristic of each, profoundly affect the agricultural value of a soil, and the soil profile, thus is a good basis for classifying soils.

To study soils satisfactorily, it is necessary to have an adequate system of nomenclature and classification for the many different kinds. General differentiations or descriptive names often used, such as "bluegrass soil", "red limestone soil", "buckshot land", are not precise enough for this purpose. The system of classifying and naming soils in general use in the United States, is that of the Division of Soil Survey of the U. S. D. A. The unit of soil classification in this system is the soil type. The name of a soil type is composed of two parts; the soil series and the soil class. Soils essentially the same in all characteristics except texture (size of mineral soil particles) belong to the same series. Series usually are named after the town near which, or the county in which the soil was first recognized. The class name merely gives the texture of a soil within the series in question. For example, Muskingum silt loam is a soil type. "Muskingum" designates a series of soils first identified in Muskingum County, Ohio, and silt loam identifies the individual soil of the Muskingum series. Muskingum loam and Muskingum sandy loam are other soil types of the Muskingum series.

¹ Agronomist—Soil Technology, Kentucky Agricultural Experiment Station.

² Soil Scientist, U. S. Department of Agriculture, Soil Conservation Service, Ohio Valley Region.

The mapping and classification of soils by this system was begun about 1900. In the earlier work, the soil series names covered a much broader range of soil conditions than now. With the development of soil classification and a growing appreciation of the importance of variations in soils, nomenclature became more exact. As a result, many new soil series names have been assigned to soils once considered variations within a series, the old series names being changed in their application or, in some cases, discarded altogether.

This Key presents in a brief and logical arrangement the soil series that are known or thought with reasonable certainty to occur in Kentucky. It should be of distinct service to workers in soils and related lines in the state in view of the fact that only a relatively small number of detailed surveys have been made in Kentucky and most of these are so old that many of the soils involved have been reclassified since the surveys were made.

The key is in two parts. The first part is the key table, in which the relationship of the various soil series to each other, based on their origin and drainage, is set forth. Horizontally, the soils in one line form a "catena", a grouping in which the origin is the same but the degree of drainage differs. Vertically, the soils appearing in each column have similar profile development but differ in point of origin of parent material. These columns are numbered 6, 5, 4, 4-3, 3, 2, 1, 7, and 8, the numbers having accepted significance as representing type of profile as follows:³

6 profile. Soils of this profile number have little or no B horizon development, the surface soil resting more or less directly upon weathered parent material. They occur on the steeper slopes and have good to excessive *surface* drainage. The subsoil color is quite varied, often depending largely upon the color of the parent material.

5 profile. Soils having a 5 profile have a definite B horizon developed, but are loose and open due to the presence, at shallow depth, of quantities of chert, gravel or sand, resulting in good to excessive *internal* drainage. Thus, they are apt to be low in water-holding capacity and drouthy. They occur, typically, on rolling to hilly topography.

4 profile. Soils with a 4 profile are the normal, mature soils developed, usually, on moderate slopes. The surface soil color is usually some shade of brown and the subsoil is some shade of red, brown or deep yellow and has little or no mottling (evidence of imperfect drainage) within 34 to 42 inches of the surface.

4-3 profile. Soils of this designation are intermediate in drainage between those having a 4 and those with a 3 profile. They are similar in color and B horizon development to the former, but at a depth of 24-34 inches a heavy or compact mottled zone⁴ occurs.

3 profile. Soils with a 3 profile generally have grayish yellow to light gray-brown surface soils underlain by yellow subsoils. Drainage is only fair, as indicated by the presence, at a depth of 14-24 inches, of a very heavy or compact layer, which is highly

³ First-bottom soils show color profile only; that is, they do not have a true B horizon of heavier-textured material below the lighter-textured surface soil, but they do develop color differences similar to those of the upland and terrace soils in accordance with the profile classification as given.

mottled with light yellow, gray, bluish gray, or rust brown mottlings and often contains a large amount of concretionary material. These soils ordinarily occur on gentle slopes.

2 profile. Soils with a 2 profile occur on practically level areas. They have gray surface soils and very light yellow to yellowish gray subsoils. Mottling with gray, bluish gray, lemon, orange or rust brown occurs above 14 inches and very heavy or compact material is found at shallow depth. Concretions usually occur thruout the profile. Both surface and internal drainage are poor.

1 profile. Soils of a 1 profile occur on level or depression areas. They are gray or whitish in the surface and predominantly gray or bluish gray in the subsoil. Concretions are often abundant, even at the surface, giving rise to the common term, "buckshot land". The subsoils are very heavy or compact and both surface and internal drainage are very poor.

7 and 8 profiles. Soils of a 7 or 8 profile occur in depressed areas and their subsoils are essentially the same as those of a 1 profile. The surface soils are vastly different, however, those of the 7 and 8 profiles having an accumulation of organic matter which gives them a dark color. Soils with a 7 profile are dark gray; those with an 8 profile very dark gray to black, the organic matter content being greater in amount.

The two are combined in the key because of their limited number and extent. These soils are quite fertile and, if properly drained, very productive, whereas the soils of number 1 profile are inherently poor.

Included in the key table is a column showing, by number, in accordance with the accompanying map, the various sections of the state in which one or more members of each catena occur.

The second and main part of the key consists of brief identification descriptions of all the soil series appearing in the key table. Sufficient information is given for each series to differentiate it from all the other series of the key. The series are described, insofar as possible, in the same catena order as they appear in the key table. The heading of each soil grouping has the same number system and wording as found in the origin column of the key sheet so as to facilitate location of the description of a particular soil series.

Several of the series names in the older Kentucky county soil survey reports of the United States Department of Agriculture, have been changed and no longer apply as then used. These are mentioned at the appropriate places in the "Remarks" line so that the present nomenclature can be determined. A few series names, previously used in Kentucky, no longer apply at all in the state. These are listed alphabetically and discussed briefly in the appendix.

The following expressions are used to describe soil reaction: alkaline, neutral, slightly acid, acid, strongly acid. The corresponding approximate pH values are: Above 7, 7 to 6, 6 to 5 and below 5.

⁴It is common to speak of a heavy, compact layer in the subsoil as the X layer.

[illegible]

A KEY TO THE KENTUCKY SOIL SERIES—Continued

Degree of drainage and profile number									
Origin	Sections of Kentucky in which found ²	Good to excessive ³ 6	Good to excessive ⁴ 5	Good 4	Medium 4-3	Fair 3	Poor 2	Very poor (gray) 1	Very poor (dark) 7 and 8
III. FIRST BOTTOM SOILS:									
1. From loess materials	13, 11			VICKSBURG		COLLINS		HAVERLY	
2. From mixed loess and coastal plain materials	13, 12			SHANNON		HYMON		KEECHY	
3. From sandstone and shale materials	{ 11, 4, 3, 2, 1 }			POPE		PHILO		ATKINS	
4. From pure or mixed limestone materials	{ 10, 9, 5, 6, 7, 8 }			HUNTINGTON	EGAM	Lindsides ^b		MELVIN	DUNNING
IV. COLLUVIAL SOILS:									
1. Local wash in sinks of uplands	9			ABERNATHY		Ooltewah ^b		BOUTHRIE	
2. Principally from loess materials	13, 11			TIGRETT		BRJENSBURG		DYER	

¹ Names of the more important and extensive soil series are in boldface type. Names in capital letters represent soil series on which the correlations are well established in Kentucky; all others are in small letters. The latter group includes: (a) Field names for soils known to exist but not yet correlated, and (b) Soils correlated in other states but not yet mapped in Kentucky, tho their occurrence is known or highly probable.

A group of miscellaneous soils, once mapped in Kentucky but now completely reclassified, is given in the appendix.

² **Symbol Legend** (See map for location)
1, 2, 3—Eastern Coalfield
4—Knobs

5—Inner Bluegrass
6—Bluegrass Hills
7—Outer Bluegrass
8—Eastern Pennyroyal

9, 10—Western Pennyroyal
11—Western Coalfield

12—Cumberland-Tennessee River Section
13—Purchase

OTR—Along Ohio, Tennessee, and possibly other rivers.

BIBH—Border of Inner Bluegrass and Bluegrass Hills.

³ These soils occur on relatively steep slopes, have little or no B horizon development, and often have excessive **surface** drainage. Internal drainage is variable.

⁴ These soils usually have excessive **internal** drainage, being open, porous, and drouthy.

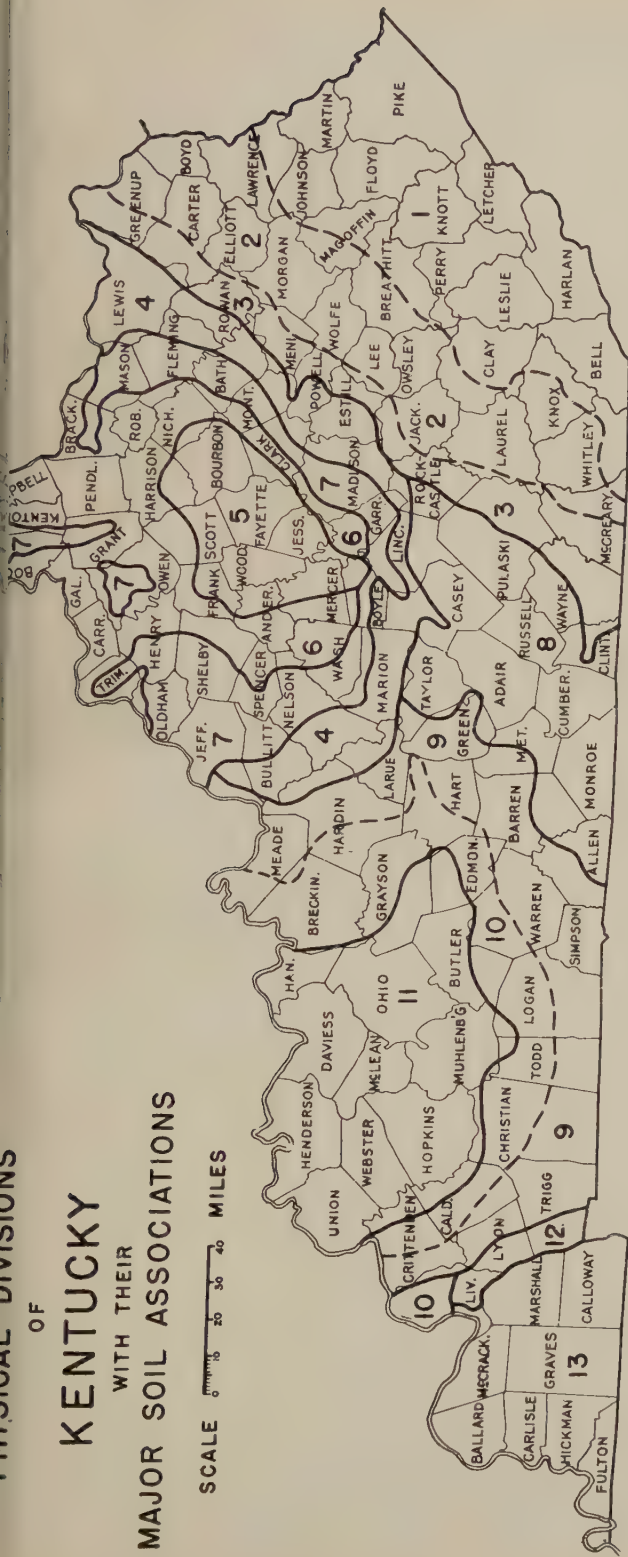
OF

KENTUCKY

WITH THEIR

MAJOR SOIL ASSOCIATIONS

SCALE 0 10 20 30 40 MILES



LEGEND

- 1 Eastern Coalfield - Eastern Belt (Muskingum - Hartsville)
- 2 Eastern Coalfield - Central Belt (Muskingum - Tilsit)
- 3 Eastern Coalfield - Western Belt (Muskingum - Westmoreland)
- 4 The Knobs (Muskingum - Colyer)
- 5 Inner Bluegrass (Maury - Loretta)
- 6 The Hills of the Bluegrass (Eden - Fairmount)
- 7 Outer Bluegrass (Shelbyville - Lowell - Nicholson)
- 8 Eastern Pennyroyal (Dickson - Baxter - Rockcastle)
- 9 Western Pennyroyal - Limestone Predominant (Decatur - Baxter - Dickson)
- 10 Western Pennyroyal - Sandstone Predominant (Hanceville - Tilsit - Christian)
- 11 Western Coalfield (Hanceville - Tilsit - Muskingum)
- 12 Cumberland - Tennessee River Section (Brandon - Bodine - Baxter)
- 13 Jackson Purchase (Memphis - Grenada - Lexington)

P. E. Karraker and W. S. Ligon
Revised Jan. 1940

IDENTIFICATION DESCRIPTIONS¹

I. UPLAND SOILS

1. Loess

Usual Topography	Rolling to gently rolling	Gently rolling	Gently rolling to undulating	Slightly undulating to level	Level
Surface Soil	Light brown to brown silt loam; acid.	Light brown to brown silt loam; acid.	Grayish brown to light brown silt loam; strongly acid.	Gray to grayish brown silt loam; strongly acid; somewhat floury; "buckshot".	Whitish gray to gray silt loam; strongly acid; very floury; "buckshot".
Subsoil	Buff or reddish brown silty clay loam to silty clay; little or no mottling or concretionary material above 34".	Buff or reddish brown silty clay loam to silty clay; gray mottling and concretionary material at 24" to 34".	Yellow to yellow brown silty clay loam; below 14"-24" mottled gray, yellow and brown, compact silty clay loam to silty clay; dark concretions.	Gray mottled with yellow and brown silty clay loam; gray increases with depth; compact at 25" to 30"; more friable below 40"; concretionary material thruout.	Gray silty clay with occasional pale yellow mottling; compact, dense, tough at 12-14"; numerous concretions, more friable below 30" to 36".
Parent Material	Loessial silt at variable depth; non-calcareous.	Loessial silt at variable depth; non-calcareous.	Loessial silt at variable depth; non-calcareous.	Loessial silt at variable depth; non-calcareous.	Loessial silt at variable depth; non-calcareous.
Natural Drainage and Profile Number	Good—4	Medium—4-3	Fair—3	Poor—2	Very poor—1
Series Name	MEMPHIS	LORING	GRENADA	CALLOWAY	HENRY
Important Textures	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam
Remarks	Mapped as bottom land, Union Co., Ky. 1902; now mapped only as well-drained loess upland.	Field name only; previously included as mottled subsoil variation of Memphis.	Previously included as poorer drained variation of Grenada.		

¹ In the following descriptions, where more than one important texture is listed, the first named is the one described. Allowances must be made for variations in profile depth and texture between different types of the same series.

I. UPLAND SOILS

1. Loess

I. UPLAND SOILS

IDENTIFICATION DESCRIPTIONS—Continued

2. Shallow Loess and Coastal Plain				3. Coastal Plain	
Usual Topography	Rolling	Gently rolling to undulating	Rolling	Rolling to gently rolling	Rolling
Surface Soil	Light brown or yellowish brown silt loam; acid.	Light brown or yellowish brown silt loam; acid.	Light brown or yellowish brown, silt loam, acid.	Light brownish yellow, mellow and friable, silt loam, acid.	Immediate surface grayish yellow loose sandy loam; underlain by yellowish brown sandy loam; acid.
Subsoil	Buff, reddish yellow or reddish brown silty clay loam; moderately compact; more friable below 30"-36", with sand influence; profile variable depending on thickness of loess.	Yellow, mottled with gray and rust brown at 14"-24", becoming compact and tough; more friable with sand or gravel influence below 30"-36".	Yellowish brown, yellowish red or buff silty clay loam, grading into gravelly coastal plain layer at 40" or less. Small amount of gravel may occur in upper part of profile. Iron-cemented gravel often present in substratum.	Yellowish brown or reddish brown heavy friable clay loam grading into mottled yellow and reddish brown firm fine sandy clay material at 40"-50".	Rust brown or reddish brown light friable sandy clay loam grading into friable sandy loam or loamy sand at 30"-35".
Parent Material	Shallow loess, 3½ feet or less, over coastal plain sands and sandy clays.	Shallow loess, 3½ feet or less, over coastal plain gravel and sand.	Shallow loess over coastal plain gravel and sand at variable depth.	Unconsolidated, stratified sandy coastal plain material.	Unconsolidated, stratified sandy coastal plain material.
Natural Drainage and Profile Number	Good—4	Fair—3	Good to excessive—5	Good—4	Good—4
Series Name	LEXINGTON	PROVIDENCE	BRANDON	ATWOOD	RUSTON
Important Textures	Silt loam, loam	Silt loam	Silt loam, gravelly loam	Silt loam, fine sandy loam	Sandy loam, gravelly sandy loam, loamy sand, gravelly loamy sand.
Remarks	The loam profile shows influence of coastal plain material thruout.		The gravelly loam has a shallower profile and is influenced thruout by coastal plain material.		Gravelly loam contains much gravel on surface; loamy sands lack fine material in B horizon.

I. UPLAND SOILS

2. Shallow Loess and Coastal Plain

2. Coastal Plain

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS				
4. Sandstone and Shale				
Usual Topography	Steep to rolling	Rolling to gently rolling	Gently rolling	
Surface Soil	Grayish brown to yellowish brown silt loam; acid; rock fragments may occur.	Grayish yellow to grayish brown silt loam, thru pale yellow, into reddish yellow; acid.	Grayish yellow silt loam, thru pale yellow, into reddish yellow, as in Hanceville; acid.	
Subsoil	Little or no B horizon development; yellowish brown silty clay loam with numerous sandstone and shale particles; partially weathered spots of yellow, gray and drab color may occur.	Reddish yellow to yellowish red friable fine sandy clay or silty clay loam; color and texture lighter below 24", but little or no mottling above 34".	Reddish yellow to yellowish red silty clay loam, as in Hanceville but mottled with gray at 24"-34"; compact mottled layer and concretionary material in lower subsoil, as in Tilsit.	
Parent Material	Sandstone and shale, generally at 20"-30".	Sandstone and shale at variable depth. Generally 50" or more.	Sandstone and shale below 86"-40", or more.	
Natural Drainage and Profile Number	Good to excessive—6	Good—4	Medium—4-3	
Series Name	MUSKINGUM	HANCEVILLE	MANITOU	
Important Textures	Silt loam, loam, fine sandy loam, gravelly loam	Silt loam, fine sandy loam, stony loam	Silt loam	
Remarks	Muskingum profile quite variable; loam, fine sandy loam, and gravelly loam profiles are lighter textured in surface and subsoil.	Most of the Hanceville stony loam as mapped in Logan and Muhlenberg Counties now would be classified as Muskingum stony loam.	Formerly considered as well-drained variation of Tilsit.	

I. UPLAND SOILS
4. Sandstone and Shale

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

4. Sandstone and Shale—Continued

Usual Topography	Gently rolling to undulating	Undulating to level	Undulating to level	Level
Surface Soil	Grayish yellow to yellowish brown silt loam; acid.	Loose dark brown to gray-black silt loam, strongly acid, 8"-10" thick, rendzina-like in appearance. Surface soil characterizes the series.	Gray to grayish yellow silt loam; acid; numerous "buckshot".	Gray, floury silt loam; acid; numerous "buckshot".
Subsoil	Yellow, or faintly reddish yellow silty clay loam; mottled with gray at 14"-24"; very compact silty or dense clay layer at 24"-34", generally underlain by highly mottled, soft concretionary zone.	Similar to Tilsit, but with brownish tinge in upper B; in poorly drained situations, subsoil more nearly resembles that of Johnsburg.	Pale yellow silty clay loam mottled with gray above 14"; very compact silty or clay layer at 18"-20". Mottling and concretions numerous in lower subsoil.	Gray silty clay loam with yellow mottling; compact or heavy, highly mottled layer at 15"-20". Strong mottling and numerous concretions in lower subsoil.
Parent Material	Sandstone and shale below 36"-40", or more.	Sandstone and shale below 36"-40", or more.	Sandstone and shale below 36"-40", or more.	Sandstone and shale at 36"-40" or more.
Natural Drainage and Profile Number	Fair—3	Fair to poor—3-2	Poor—2	Very poor—I
Series Name	TILSIT	NEBO	JOHNSBURG	MULLINS
Important Textures	Silt loam, very fine sandy loam	Silt loam	Silt loam	Silt loam
Remarks		A peculiar variation of Tilsit found in Hopkins Co., Ky., in very limited amount. May occur in very small amounts elsewhere.	Formerly included as poorly drained variation of Tilsit.	Mapped in Rockcastle Co., Ky., 1910, as very shallow hillside soil derived from Waverly shales. Now held to soil described above and, as such, not mapped in Ky., but occurs.

I. UPLAND SOILS

4. Sandstone and Shale—Continued

IDENTIFICATION DESCRIPTIONS:—Continued

I. UPLAND SOILS

4. Sandstone and Shale—Continued				
Usual Topography		Steep to gently rolling		
Surface Soil		Rolling to gently rolling	Steep to rolling	Steep to rolling
	Grayish yellow to pale brown, mellow, friable, single-grained fine sandy loam; acid.	Brownish gray, acid silt loam, often containing water-worn gravel.	Reddish brown clay; slightly acid to neutral.	Mixed soil; silty clay loam spotty in color and texture; acid.
Subsoil	Yellow, brownish yellow, to pinkish or reddish yellow sandy clay loam, firm but friable, grading at 34" or more thru yellow mottled with reddish brown, or grayish, into soft disintegrated sandstone.	Deep reddish yellow silty clay loam, sometimes grading at 24" or more into reddish yellow material somewhat mottled with gray, and containing sand and sometimes water-worn gravel. Variable. In places little profile development and large quantities of partially disintegrated cemented conglomerate.	Very heavy plastic red or purplish red clay; below 24" less plastic, black coatings of fine material on breakage faces, and containing some gritty material.	Mixed Muskingum and Upshur.
Parent Material	Soft gray or yellow sandstone at variable depth, usually 30"-40".	Soft red sandstone, sometimes with hard cemented conglomerate, at variable depth.	Red calcareous clay shale at 24"-40".	Sandstone, shale, and red clay shale at 24"-36".
Natural Drainage and Profile Number	Good—4	Excessive to medium—6 to 4-3	Good to excessive—6	Good to excessive—6
Series Name	HARTSELLS	HECTOR	UPSHUR	MEIGS
Important Textures	Fine sandy loam	Silt loam, very fine sandy loam	Clay	Silty clay loam
Remarks	Depth of profile variable. Not yet mapped in Ky., but very probably occurs in considerable amount.	Field name for soil known to occur in Ky., where lower layers of the coal measures and upper layers of Chester soft sandstones are exposed.	Not yet mapped in Ky., but limited occurrence probable.	Very spotty and variable, making separation of Muskingum and Upshur impossible; not yet mapped in Ky., but limited occurrence probable.

I. UPLAND SOILS

4. Sandstone and Shale—Continued

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

4. Sandstone and Shale—Continued

Usual Topography		Steep to rolling		Gently rolling to undulating		Steep to gently rolling	
Surface Soil	Grayish yellow to light brown silt loam containing large quantities of shale fragments of gray, olive, and blue gray color; strongly acid.			Grayish brown heavy silt loam; strongly acid.		Grayish brown to light brown silt loam; strongly acid; may contain small shale fragments.	
Subsoil	Yellow silty clay with little or no B horizon, passing into mottled gray and yellow silty clay; large quantities of shale fragments.	Yellow plastic silty clay loam; at 14"-24" mottled red, gray, and yellow plastic clay; underlain at 27"-37" by disintegrated shale above unweathered shale.				Yellowish brown to pale yellow silty clay loam to silty clay, with numerous shale particles, increasing in amount with depth.	
Parent Material	Gray, dull olive and bluish gray Waverly shale at 12"-24".	Gray shales at about 50".				Black oil shales at 18"-30".	
Natural Drainage and Profile Number	Excessive—6	Fair—3				Good to excessive—6	
Series Name	ROCKCASTLE	FAWOETT				COLYER	
Important Textures	Shale loam	Silt loam				Silt loam	
Remarks	Field name for much of the soil mapped in Rockcastle Co., Ky., 1910, as Lickdale.	Not mapped, as yet, in Ky., but occurrence very probable.				A steep phase and a deep phase are mapped in Ohio (1938). In the former, the profile is very shallow with numerous shale outcrops. The deep phase occurs on gentle slopes with shale at greater depth, has only fair drainage, and is more similar to the Colyer silt loam as mapped in Rockcastle Co., Ky., 1910.	

I. UPLAND SOILS

4. Sandstone and Shale—Continued

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

5. Mixed Acid Sandstone, Acid Shale, and Limestone

Usual Topography	Steep to rolling	Rolling	Rolling to undulating	Gently rolling to undulating
Surface Soil	Variable grayish brown, yellowish brown, or dark brown silty clay loam with areas of silt loam; slightly acid to neutral.	Yellowish brown to brown silt loam; reaction moderately to slightly acid.	Light brown, mellow silt loam with very faint splotches of gray and yellow; acid.	Light grayish brown, loose or mellow silt loam; acid.
Subsoil	Little or no B horizon development; yellowish brown to yellow-olive heavy silty clay; partially weathered spots of yellow, gray, and drab color usually occur; rock fragments of sandstone, shale, and limestone sometimes occur.	Yellowish red, reddish brown, or brownish red silty clay loam; B horizon usually definite but shallow; lower subsoil variable in texture and color due to mixed origin.	Yellowish red or reddish brown friable silty clay; at 20"-24", yellowish red, dense, firm, tough, but not plastic, silty clay or silty clay loam, grading at 32" to 36" into moderately firm brownish silty clay loam splotched with gray and yellow.	Yellow or light yellowish brown silty clay, firm and moderately tough; at 14"-24" dense, compact, tough silty clay, brown mottled with gray and yellow.
Parent Material	Sandstone, shale, and limestone, generally at 24"-36".	Sandstone, shale, and limestone at variable depth.	Sandstone, shale, and limestone at variable depth, usually 40"-60".	Sandstone, shale, and limestone, usually at 40"-60".
Natural Drainage and Profile Number	Good to excessive—6	Good to excessive—6	Good—4	Fair—3
Series Name	WESTMORELAND	CANEYVILLE	CHRISTIAN	NOLIN
Important Textures	Silty clay loam	Silty clay loam, stone clay loam	Silt loam	Silt loam
Remarks	A mixed soil. Similar to Muskingum but derived partly from limestone. Differs from Christian by having no definite B horizon and no red color in subsoil. Has not been mapped in Ky. but occurrence is known.	Quite variable as to texture, color, and profile depth.	Previously mapped more widely.	Field name for soil known to exist in Kentucky.

I. UPLAND SOILS

5. Mixed Acid Sandstone, Acid Shale, and Limestone

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)

Usual Topography		Gently rolling to gently undulating	Rolling to gently undulating	Gently rolling to gently undulating	Gently rolling to undulating
Surface Soil		Brown to reddish brown. mel-low silt loam; acid.	Brown, smooth silt loam; acid.	Yellow gray to light brown mellow silt loam; acid.	Smooth, friable, yellowish gray to light brown silt loam; acid.
Subsoil		Firm, dense, brittle, deep red to maroon red silty clay to depth of 5-7 feet; rests directly on bedrock or heavy tough spotted red, yellow and gray layer just above the bedrock.	Brown silty clay loam, friable, crumbly; becomes more compact below 16"-20"; at 36", heavy reddish brown to deep red silty clay extending to bedrock.	Yellow or yellowish brown silty clay loam, slightly mottled with gray below 24"-34".	Yellow or brownish yellow silty clay loam, below 14"-24", compact and mottled gray, yellow, and rust-brown; at 40", tenacious red clay sometimes occurs.
Parent Material		High grade limestone, usually; sometimes cherty at 5-8 feet.	High grade limestone, at variable depth.	High grade limestone, at variable depth, usually 8 feet or more.	High grade or slightly cherty limestone at 5-8 feet.
Natural Drainage and Profile Number		Good—4	Good—4	Medium—4-3	Fair—3
Series Name		DECATUR	HAGERSTOWN	RUSSELLVILLE	BEDFORD
Important Textures		Silt loam, clay loam	Silt loam, stony silt loam	Silt loam	Silt loam
Remarks		The clay loam as mapped in Logan County mainly was derived from the silt loam by erosion.	Mapped very widely in past, once including practically all limestone soils in central and western Ky.; similar in appearance to Maury but lacks its high phosphate content.	Field name for better drained phase of soil mapped as Clarksville in Logan Co., Ky., 1919.	Not mapped as yet in Ky., but described in Logan Co. Survey, 1919, as a variation in the Clarksville mapped.

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)—Continued			
Usual Topography	Gently undulating to level	Level or depression	Level or depression
Surface Soil	Gray to yellowish gray or light brownish gray, very friable silt loam; acid; 'buck-shot' sometimes plentiful.	Whitish, gray, or light brownish gray floury silt loam; acid; numerous 'buck-shot'.	Very dark brown to black, heavy silty clay loam; alkaline to slightly acid.
Subsoil	Light brown compact silt loam mottled with yellow above 14", or yellow to pale yellow mottled with gray above 14"; at 20"-30" tough heavy clay mottled yellow and bluish gray, or compact mottled gray and brown silty clay loam sometimes immediately underlain by red clay. Concretions often numerous above red clay layer.	Light gray, whitish, or bluish gray often mottled with yellow and rust brown; concretions numerous; may be friable just under surface, but passes quickly into very compact silty layer or very tough, plastic clay layer, or thru one into the other within a depth of 3 feet.	Dull gray and yellow mottled very plastic and sticky clay.
Parent Material	High grade limestone or mixed limestone, shale, and sandstone at variable depth, usually 5 feet or more.	High grade or cherty limestone, or mixed limestone, shale and sandstone at variable depth, usually 8 feet or more.	Limestone, or mixed limestone and shale at 6 feet or more, with influence of colluvial and alluvial wash from adjacent areas.
Natural Drainage and Profile Number	Poor—2	Very poor—1	Very poor—8
Series Name	LAWRENCE	GUTHRIE	BURGIN
Important Textures	Silt loam	Silt loam, silty clay loam	Silty clay loam, clay loam
Remarks	Not mapped as yet in Ky., but included as variation in Clarksville of Logan Co., Ky., 1919. Probably has rather wide occurrence in Ky.	Mapped as very poorly drained upland soil in all catenas of limestone or part limestone origin in which the number 1 profile occurs. Also mapped as the 1 profile in limestone sinks.	Originally mapped over phosphatic Trenton limestone only; due to small occurrence, it now includes the 8 profile of all limestone catenas in which such profile occurs. Found in upland depressions and along incipient drainage ways.

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)—Continued

IDENTIFICATION DESCRIPTIONS!—Continued

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)—Continued

Usual Topography		Steeply rolling to rolling		Steeply rolling to rolling		Gently rolling to undulating		Undulating to level	
Surface Soil		Brownish gray silt loam; acid; chert fragments may occur.		Light brownish gray; cherty silt loam; acid.		Light brownish gray silt loam grading into pale yellow; acid.		Yellowish gray, to pale yellow silt loam; acid.	
Subsoil		Yellowish red silty clay loam passing at 18"-20" into reddish silty clay or clay, very cherty, chert content increasing with depth.		Yellow to yellowish brown friable clay loam with faint spots of red, yellow, and gray, particularly in lower part; chert abundant, increasing with depth; chert beds at 30".		Pale yellow or yellow heavy silty clay loam or clay loam; below 16"-26" compact silty clay, yellow with gray mottlings or streaks, sometimes with reddish brown; below 40"-48" red clay mottled with yellow or gray; some chert occurs throughout subsoil, increasing with depth.		Pale yellow silty clay loam; at 16" or less, pale yellow silty clay mottled with gray; concretions are usually plentiful; gray increases with depth; compact in lower subsoil; chert fragments occur within three-foot section.	
Parent Material		Very cherty limestone at 20-30 feet or less.		Very cherty limestone at 20-30 feet or less.		Cherty limestone at 20-30 feet or less.		Cherty limestone at variable depth.	
Natural Drainage and Profile Number		Good to excessive—5		Excessive—5		Fair—3		Fair—2	
Series Name		BAXTER		BODINE		DICKSON		LEBANON	
Important Textures		Silt loam, cherty silt loam		Cherty silt loam, silt loam		Silt loam		Silt loam	
Remarks		Not mapped as yet in Ky. but named and described as variation in Decatur gravelly clay loam in Logan Co., Ky., 1919. Occurs in considerable amount.		Silt loam has little or no chert in surface soil.		Not mapped as yet in Ky. but is known to occur extensively. Typical position is on ridge tops above Baxter or Bodine slopes.		Differs from Lawrence by being derived from cherty limestone rather than high grade limestone or mixed limestone and shale, lower subsoil is usually compact rather than heavy, and parent material is at greater depth.	

I. UPLAND SOILS

6-a. Limestone (Mississippian, Devonian, and Silurian)—Continued

IDENTIFICATION DESCRIPTIONS¹—Continued

I. UPLAND SOILS

6-b. Limestone (Richmond and Maysville)

Usual Topography		Gently rolling to undulating		Undulating		Rolling to gently rolling		Gently rolling to undulating	
Surface Soil		Light brown to yellowish brown friable silt loam; acid.		Gray brown to yellowish brown silt loam; acid.		Brown, mellow silt loam; acid.		Brown, deep mellow silt loam; acid.	
Subsoil		Yellow to yellowish brown moderately stiff silt loam becoming silty clay loam becoming heavier and more compact with depth. May be mottled with gray at 34".		Yellow or yellowish brown silt loam to silty clay loam, becoming mottled with gray and more compact below 18"-20".		Brownish yellow or yellowish brown silty clay loam to silty clay, passing gradually through brownish yellow or yellow plastic clay; at 24"-34" greenish yellow or mottled yellow and greenish yellow plastic clay; little or no concretions material.		Yellow to yellow brown, moderately friable silty clay loam; at 20"-30" yellow crumbly silty clay containing small black concretions and dark friable concretionary material in great abundance.	
Parent Material		Predominantly siltstone at 6 feet or more.		Predominantly siltstone at 10 feet or more.		Predominantly Richmond limestone at variable depth.		Predominantly Maysville limestone at 4 feet or more.	
Natural Drainage and Profile Number		Good—4		Fair—3		Medium—4-3		Medium—4-3	
Series Name		NICHOLSON		KENTON		LOWELL		SHELBYVILLE	
Important Textures		Silt loam		Silt loam		Silt loam		Silt loam	
Remarks		Old well-drained soil from Maysville-Richmond formations, remnants of which occur on broad watershed divides above Eden formation; included in Cincinnati as mapped in Shelby Co., Ky., 1916.		Field name for soil of same origin as Nicholson, but of poorer drainage.		Stiffer in subsoil than Nicholson, much less concretionary material than Shelbyville; more profile development and more acid than Fairmount. More friable in upper subsoil than Maddox.		Distinguished by abundance of concretionary material in lower B horizon.	

I. UPLAND SOILS

6-b. Limestone (Richmond and Maysville)

IDENTIFICATION DESCRIPTIONS!—Continued

I. UPLAND SOILS

6-c. Limestone (Eden and Cynthiana)

Usual Topography	Steep to rolling	Steep to rolling	Moderately steep	Rolling to gently rolling	Gently rolling
Surface Soil	Dark brown to gray-black, silty clay loam; very slightly acid to slightly alkaline. Limestone slabs common on surface.	Brown silty clay loam with reddish brown to slightly acid to slightly alkaline; many areas are stony, with limestone and shale exposed in places.	Brown to gray, brown silty clay loam, slightly acid to neutral; limestone slabs often found on surface.	Brown, mellow silt loam; slightly acid.	Gray brown to brown silty clay loam with specks of red in sub-surface; acid.
Subsoil	No B horizon development; yellow and olive weathered parent material, very heavy, tough and plastic; limestone slabs plentiful.	Reddish brown, very heavy, tough and plastic; differs from Fairmount principally in color; limestone slabs plentiful.	Definite, though usually shallow, B horizon of yellow to yellow brown silty clay loam becoming paler and more plastic with depth; at 14"-20" yellow and olive weathered parent material, very heavy.	Brownish yellow or yellowish brown heavy silty clay, passing quickly into brownish yellow or yellow very heavy plastic clay. Lower subsoil greenish yellow heavy clay.	Yellow to light brown silty clay loam with red mot-tles overlying yellow and olive heavy plastic clay streaked with red seams.
Parent Material	Limestone and calcareous shale at 24"-36"; limestone usually predominates.	Limestone and calcareous shale at 30"-40" or more.	Limestone and calcareous shale at 30"-40" or less; shale usually predominates.	Limestone and calcareous shale at 40" or more; limestone usually predominates.	Limestone and calcareous shale at 18"-40"; limestone predominates.
Natural Drainage and Profile Number	Good to excessive—6	Good to excessive—6	Good to excessive—6	Good—4	Fair—3
Series Name	FAIRMOUNT	HEITT	EDEN	MADDOX	ELLSBERRY
Important Textures	Silty clay loam, stony silty clay loam	Silty clay loam	Silty clay loam, silt loam, clay loam	Silt loam	Silty clay loam
Remarks		As mapped in Ohio; not mapped in Kentucky but occurrence likely.		Differs from Lowell being much heavier in upper subsoil.	As mapped in Ohio; limited occurrence in Kentucky likely.

I. UPLAND SOILS

6-c. Limestone (Eden and Cynthiana)

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

6-c. Limestone (Eden and Cynthiana)—Continued		6-d. Limestone (Cynthiana)	
Usual Topography	Steep to rolling	Rolling to gently rolling	Gently rolling to undulating
Surface Soil	Light brown to brown mellow silt loam, slightly acid; rock fragments of limestone and sandstone plentiful.	Dull brown or grayish brown silty clay loam; slightly acid to alkaline; outcrop of rock ledges common.	Loose, mellow, brown silt loam, acid.
Subsoil	Yellow to yellowish brown friable silt loam or silty clay loam; in places plastic yellow clay as in Eden, in others considerable sand occurs.	Drab granular or heavy plastic silty clay or clay; shallow; may contain large quantities of calcareous shale material.	Brownish yellow silty clay loam grading, with depth, to yellow plastic clay at 3 feet or less; acid.
Parent Material	Limestone and calcareous shale, with sandstone occurring in variable amounts; average depth to rock 30".	Fragmentary limestone or interbedded limestone and calcareous shale at 1-3 feet; outcrops common.	Thin-bedded limestone at 5-10 feet or more.
Natural Drainage and Profile Number	Good to excessive—6	Good to excessive—6	Good—4
Series Name	CULLEOKA	SALVISA	LORADALE
Important Textures	Gravelly silt loam, stony	Silty clay loam	Silt loam
Remarks	A mixed soil, due to presence of Garrard sandstone in the Eden formation.	Thin soil mapped at border of bluegrass hills and inner bluegrass regions, on parent material of each.	Surface similar to that of Maury, but more acid. Subsoil heavier than in Maury, much more acid, and becomes lighter in color with depth.

I. UPLAND SOILS

6-c. Limestone (Eden and Cynthiana)—Continued

6-d. Limestone (Cynthiana)

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

6-e. Limestone (Trenton phosphatic)				
Usual Topography	Gently rolling to undulating	Gently rolling to undulating	Gently rolling to undulating	Level
Surface Soil	Rich dark brown heavy silt loam; slightly acid to acid.	Very mellow loose friable rich brown or reddish brown silt loam; lighter brown sub-surface to 20", very friable and slightly granular; slightly acid to acid.	Loose, dull brown, silt loam; varying quantities of angular chert are common; acid.	Very dark brown to black, heavy silty clay loam; alkaline.
Subsoil	Brownish red to chocolate brown silty clay to clay loam, heavier and less friable than Maury, but not plastic; very high phosphate content.	Rich reddish brown silty clay loam; high phosphate content.	Similar to Maury, but more compact, plastic, or clay-like and contains considerable quantities of angular chert and siliceous materials in lower subsoil.	Dull gray and yellow mottled clay, very plastic and sticky.
Parent Material	Highly phosphatic Trenton limestone at 4-7 feet.	Phosphatic Trenton limestone at variable depth, average 8 feet.	Cherty Trenton limestone at 2-10 feet.	Phosphatic Trenton limestone with influence of colluvial and alluvial wash from adjacent limestone soil areas.
Natural Drainage and Profile Number	Good—4	Good—4	Good to excessive—5	Very poor—8
Series Name	McAFEE	MAURY	BRAXTON	BURGIN
Important Textures	Silt loam, silty clay loam	Silt loam, silty clay loam, stony silt loam	Silt loam	Silty clay loam, clay loam
Remarks	Highly phosphatic soil; similar to Maury but heavier and somewhat deeper colored, and usually higher in phosphorus content.	Numerous phases are mapped: yellow, gray brown, slope, shallow, terrace, colluvial.	Field name for soil mapped in Fayette Co., Ky., 1938, as Maury, imperfectly drained phase.	Found in upland depressions and along incipient drainage ways. Now included in other limestone soil catenas in which the 8 profile appears.

I. UPLAND SOILS

6-e. Limestone (Trenton phosphatic)

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

7-a. Glacial Till (Illinoian)

Usual Topography		Rolling to gently rolling		Gently rolling to undulating		Undulating to level		Level	
Surface Soil		Dark grayish brown to brown friable silt loam; acid.		Grayish brown to light yellowish brown friable silt loam; strongly acid.		Brownish gray to yellowish gray friable silt loam; strongly acid.		Gray, "buckshot" numerous.	
Subsoil		Yellowish brown to brown heavy silt loam to silty clay loam to 48"; below 48", usually brown or yellowish brown plastic silty clay with faint light mottlings; occasional pebbles of crystalline rock and chert throughout profile.		Light yellowish brown rather compact silty clay loam becoming slightly heavier with depth, and mottled with light gray and brown below 20"-24"; glacial gravel and sand common below 30".		Pale yellowish gray silty clay loam with yellow and brown stains, increasing in size of color splotches, lightness of gray color and heavier in texture to 48". Glacial pebbles numerous in lower subsoil.		Rather compact gray or pale yellowish gray silt loam mottled slightly with yellowish brown and becoming lighter in color with depth; below 18"-24", gray or grayish yellow heavy plastic clay containing iron concretions and yellow-brown mottlings; chert and crystalline rock pebbles numerous below 40".	
Parent Material		Glacial drift at 6-10 feet.		Glacial drift at 6-10 feet.		Glacial drift at 6-10 feet.		Glacial drift at 6-10 feet.	
Natural Drainage and Profile Number		Good—4		Fair—3		Poor—2		Very poor—1	
Series Name		CINCINNATI		ROSSMOYNE		AVONBURG		CLERMONT	
Important Textures		Silt loam		Silt loam		Silt loam		Silt loam	
Remarks		As glacial soil, not yet mapped in Ky., but identified. Previously mapped in Ky. as residual soil embracing the present Nicholson and Lowell series.		Not yet mapped in Ky., but tentatively identified.		Not yet mapped in Ky., but identified.		Not yet mapped in Ky., but identified.	

I. UPLAND SOILS

7-a. Glacial Till (Illinoian)

IDENTIFICATION DESCRIPTIONS—Continued

I. UPLAND SOILS

7-a. Glacial Till (Illinoian)—Continued				7-b. Very Old Till or Glacial Terrace (Kansan?)	
Usual Topography	Steeply rolling to rolling	Gently rolling to undulating	Rolling	Gently rolling	
Surface Soil	Dark grayish brown to brown friable silt loam; acid.	Grayish brown to yellowish brown friable silt loam; acid.	Gray brown fine sandy loam; acid.	Grayish brown silt loam; acid.	
Subsoil	Yellowish brown silty clay loam of glacial origin, becoming heavier and mottled with depth, grading into heavy residual calcareous shale and limestone material at about 30"-40". Glacial chert and crystalline rock pebbles may occur in upper part of profile.	Yellowish brown rather compact silty clay loam, mottled with gray and yellow below 18"-24", grading downward into heavy partially weathered residual calcareous shale and limestone at 40"-50".	Brownish friable sandy clay. Below 36" yellow brown, friable, sandy material which may contain heavy lenses. Stratification readily apparent. Carbonates at 10 ft. or more. Calcareous conglomerate including erratic rocks sometimes occurs.	Yellowish brown silty clay loam with small nut structure. 24"-34" yellow and gray mottled hard silty layer grading into red and yellowish red sandy clay containing scattered pebbles.	
Parent Material	Shallow glacial drift over calcareous shale and limestone.	Shallow glacial drift over calcareous shale and limestone.	Stratified sandy material with gravel and clay lenses at 10-30 feet.	Stratified sandy materials with gravel and clay lenses, at 25-30 feet, above calcareous sand.	
Natural Drainage and Profile Number	Good to excessive—6	Fair—3	Good to excessive—5	Medium—4-3	
Series Name	EDENTON	LOUDON	PARKE	COVINGTON	
Important Textures	Silt loam	Silt loam	Fine sandy loam, silt loam	Silt loam	
Remarks	Not yet mapped in Kv. but identified. Resembles Cincinnati in upper part of profile and Fairmount in lower part.	Not yet mapped in Ky. but occurrence likely. Similar to Rossmoyne in upper part of profile, but lower part is from residual material rather than glacial drift.	Believed to be glacial terrace soil from very old glaciation, probably Kansan. Deeply weathered. Occurs along Ohio River bluffs in northern Kentucky.	Field name for soil believed to be of old glacial terrace origin. Deeply weathered. Occurs along Ohio River bluffs in northern Kentucky.	

I. UPLAND SOILS

7-a. Glacial Till (Illinoian)—Continued

7-b. Very Old Till or Glacial Terrace (Kansan?)

IDENTIFICATION DESCRIPTIONS¹—Continued

II. TERRACE SOILS

1. From Loess Materials				
Usual Topography	Gently undulating	Gently undulating	Gently undulating to level	Gently undulating to level
Surface Soil	Light brown, brown or yellowish brown silt loam; acid.	Light brown silt loam; acid.	Grayish brown to light brown silt loam grading into yellow; acid.	Gray to grayish-brown silt loam, acid.
Subsoil	Brownish yellow, reddish brown or buff silty clay loam; lower subsoil paler yellow and may contain a small amount of concretionary material but little or no gray mottling above 34".	Light brownish-yellow, silty clay loam, yellow with gray and brown mottlings below 18-24 inches, some concretionary material.	Yellow silty clay loam mottled below 14"-24" with gray, bluish gray, rusty brown, and yellow; lower subsoil compact and tough; concretionary material throughout profile.	Yellowish-gray to gray silty clay loam, mottled below 12-15 inches; lower subsoil, dense and impervious; concretionary material thru profile.
Parent Material	Old alluvial silt from loess uplands, at 40" or more.	Old alluvial silt from loess uplands, at 40" or more.	Old alluvial silt from loess uplands, at 40" or more.	Old alluvial silt from loess uplands, at 30" or more.
Natural Drainage and Profile Number	Good—4	Moderately good—4-3	Fair—3	Very poor—1
Series Name	LINTONIA	RICHLAND	OLIVIER	CARROLL
Important Textures	Silt loam	Silt loam	Silt loam	Silt loam
Remarks				

II. TERRACE SOILS

1. From Loess Materials

IDENTIFICATION DESCRIPTIONS—Continued

II. TERRACE SOILS

2. From Mixed Loess and Coastal Plain Materials

Usual Topography	Undulating	Undulating to level	Undulating to level	Level
Surface Soil	Brown gravelly loam, acid.	Light brown or yellowish brown silt loam; acid.	Light brown or grayish brown silt loam grading into yellow; acid.	Gray or mottled light gray, grayish brown and rusty brown loam; acid.
Subsoil	Light brown or slightly yellowish-brown gravelly loam; below 12-15 inches light brown loose gravel.	Yellow, reddish yellow or buff silty clay loam or clay loam, becoming paler and more friable in lower subsoil; little or no mottling.	Yellow, mottled below 14"-24" with gray, rusty brown, and yellow, clay loam or silty clay, moderately compact; concretionary material throughout profile.	Light gray loam, mottled with yellow and rusty brown; at 18"-25", gray clay loam or silty clay, mottled, compact and tough; concretions numerous thruout profile.
Parent Material	Mainly sand and gravel.	Silt, sand and gravel, often stratified; average depth 40".	Silt, sand and gravel, often stratified; average depth 40".	Silt, sand and gravel, often stratified; average depth 40".
Natural Drainage and Profile Number	Excessive-5	Good-4	Fair-3	Very poor-1
Series Name	Iola	DEXTER	FREELAND	ALMO
Important Textures	Gravelly loam	Silt loam, loam, gravelly sandy loam.	Silt loam, loam, sandy loam	Loam
Remarks	Inextensive, used mainly for gravel pits.	Similar to Lintonia, except for presence of sand and gravel particles of coastal plain origin.	Similar to Olivier except for presence of sand and gravel particles of coastal plain origin.	Similar to Calhoun except for presence of sand and gravel particles of coastal plain origin.

II. TERRACE SOILS

2. From Mixed Loess and Coastal Plain Materials

IDENTIFICATION DESCRIPTIONS—Continued

II. TERRACE SOILS

3. From Sandstone and Shale Materials

Usual Topography	Rolling to gently undulating	Rolling to gently undulating	Undulating to level	Level	Level
Surface Soil	Brown to reddish brown mellow, friable, fine sandy loam; acid.	Yellowish brown to brown-gray silt loam; acid.	Grayish brown to gray loose silt loam becoming yellowish brown with depth; acid.	Gray silt loam, strongly acid; "buckshot" abundant.	Gray silt loam, strongly acid; "buckshot" abundant.
Subsoil	Dull red, light red, or yellowish red, stiff, slightly compact but brittle clay or heavy fine sandy clay.	Yellowish brown, heavy silt loam; below 24" yellowish brown silt loam or loam; no mottling to depth of 36" or more.	Yellowish brown silty clay loam; below 14" 24", heavy compact silt loam or silty clay loam, mottled with gray and yellow.	Mottled yellowish brown and gray silty clay; below 24" compact heavy silt loam or clay, gray with slight yellowish brown mottling; concretions usually plentiful.	Gray silty clay with slight yellow mottlings and concretions; tough or compact heavy silt loam or clay at 18"-24" gray, blue gray, and yellow mottlings and numerous iron concretions occur in lower subsoil.
Parent Material	Sands, gravels, silts and clays at 36" or more.	Stratified sands, silts, below 36"-48".	Stratified silt and clay below 36"-48".	Stratified silt and clay below 30"-40".	Stratified silt and clay below 30"-40".
Natural Drainage and Profile Number	Good—4	Good—4	Fair—3	Poor—2	Very poor—1,
Series Name	WAYNESBORO	HOLSTON	MONONGAHELA	TYLER	PURDY
Important Textures	Fine sandy loam, silt loam	Silt loam, loam, very fine sandy loam	Silt loam	Silt loam	Silt loam
Remarks	Not yet mapped in Ky., but occurrence likely. No limestone materials as in Elk and Cumberland; differs from Holston by having red color and more gravel in subsoil.	Occurs in Ky., but not yet mapped; previously included with Elk.	Not yet mapped, but has wide occurrence in Ky.; previously included with Elk.	Not yet mapped in Ky., but occurrence known.	Not yet mapped in Ky., but occurrence very probable.

II. TERRACE SOILS

3. From Sandstone and Shale Materials

IDENTIFICATION DESCRIPTIONS—Continued

II. TERRACE SOILS

4. From Pure or Mixed Limestone Materials

Usual Topography	Gently rolling	Undulating to level	Undulating to level	Level
Surface Soil	Brown, or yellowish brown, mellow silt loam; acid.	Usually yellowish brown silt loam, slightly acid; may have grayish or slightly reddish tinge.	Grayish brown to yellowish brown silt loam; acid.	Yellow gray, gray, or light gray silt loam; strongly acid; "buckshot" numerous.
Subsoil	Brownish yellow or reddish yellow silty clay loam; below 18" reddish brown or reddish yellow clay loam; lower subsoil contains chert, gravel, geodes, or other coarse material.	Yellowish brown to yellow silty clay loam; heavy in upper B, more friable in lower B. Little or no mottling in 3-ft. section; may have reddish tinge in upper B.	Yellowish brown to yellow friable silty clay loam; below 14"-24" compact silty clay loam mottled yellow and gray; concretionary material generally present.	Silty clay loam, gray or highly mottled yellow, gray, blue gray, rust brown; usually tough and slowly pervious.
Parent Material	Old alluvium, high above present stream level, of silts and clays with sands, gravels and other coarse material, at 4 feet or more.	Largely silts and clays, with little or no sand and gravel, at average depth of 3-4 feet.	Largely silts and clays, with little or no sand and gravel, at average depth of 3 feet.	Stratified silt and clay below 30"-40".
Natural Drainage and Profile Number	Good to excessive—5	Good—4	Fair—3	Very poor—1
Series Name	CUMBERLAND	ELK	CAPTINA	ROBERTSVILLE
Important Textures	Silt loam, gravelly loam	Silt loam	Silt loam	Silt loam
Remarks	Phases mapped which vary from typical silt loam, are cherty, shallow, heavy subsoil; gravelly loam is 50%-80% chert, gravel, and geodes, and is non-arable.	Previously mapped very broadly in Ky., on terraces of various origin and of fair to well-drained profile.	Occurs in Ky., but not yet mapped; previously included with Elk.	

II. TERRACE SOILS

4. From Pure or Mixed Limestone Materials

IDENTIFICATION DESCRIPTIONS¹—Continued

II. TERRACE SOILS

4. From Pure or Mixed Limestone Materials—Continued

Usual Topography	Gently undulating	Level	Level	Level or depression
Surface Soil	Dark brown or brown silt loam; slightly acid.	Grayish brown silt loam; acid.	Gray silt loam; strongly acid; numerous "puckshot" concretions.	Dark gray, or dark olive gray, silty clay loam; slightly acid to neutral.
Subsoil	Brown, light brown, or yellowish brown moderately compact, silty clay loam, grading into loam at 50"; no mottling above 42", but soft concretions may occur. Small mica flakes occur thruout profile.	Yellowish brown silty clay loam; compact and mottled with gray, brown, and yellowish brown below 14"-24". Lighter in texture below 45". Mica flakes thruout profile. Concretions numerous in lower subsoil.	Gray, mottled with yellowish brown, silty clay loam or clay loam; compact and impervious; lighter texture below 42"; concretions and concretionary material abundant.	Gray plastic silty clay loam with dark brown mottlings, to depth of 4 feet or more.
Parent Material	Stratified sand, gravel, etc., below 60"-84".	Stratified sand, gravel, etc., below 60"-84".	Stratified sand, gravel, etc., below 60"-84".	Stratified sand, gravel, etc., below 60"-84".
Natural Drainage and Profile Number	Good—4	Fair—3	Very poor—1	Very poor—7
Series Name	WHEELING	SCIOTOVILLE	GINAT	CHILO
Important Textures	Silt loam, very fine sandy loam	Silt loam, very fine sandy loam	Silt loam	Silty clay loam, silt loam, loam
Remarks				As mapped in Ohio; limited occurrence probable in Ky.

II. TERRACE SOILS

4. From Pure or Mixed Limestone Materials—Continued

IDENTIFICATION DESCRIPTIONS—Continued

III. FIRST BOTTOM SOILS

1. From Loess Materials

Usual Topography	Level	Level	Level
Surface Soil	Light brown or grayish brown, smooth, mellow silt loam; slightly acid.	Grayish brown, smooth silt loam; acid.	Brownish gray to gray silt loam, often mottled with brown, rusty brown or yellow; acid; "buckshot" plentiful.
Subsoil	Yellowish brown or brown friable silt loam with little or no mottling or concretions above 36".	Light brown, pale yellowish brown, or grayish brown often with some concretionary material; below 14", light gray or bluish gray friable silt loam, mottled with yellow and brown, and containing concretions.	Light gray, gray, or bluish gray silt loam to silty clay loam, mottled with brown, yellow, or grayish brown; friable concretionary material abundant.
Parent Material	Recent alluvium from loess uplands.	Recent alluvium from loess uplands.	Recent alluvium from loess uplands.
Natural Drainage and Profile Number	Good—4	Fair—3	Very poor—1
Series Names	VICKSBURG	COLLINS	WAVERLY
Important Textures	Silt loam	Silt loam	Silt loam
Remarks			Mapped as "black bottoms", Union Co., Ky., 1902. Now held to soil described above.

III. FIRST BOTTOM SOILS

1. From Loess Materials

IDENTIFICATION DESCRIPTIONS¹—Continued

III. FIRST BOTTOM SOILS

2. From Loess and Coastal Plain Materials			
Usual Topography	Level	Level	Level
Surface Soil	Light brown or grayish brown loam, slightly acid.	Grayish brown loam; acid.	Gray or whitish gray loam, often mottled with brown, rusty brown, or yellow; acid; "buckshot" plentiful.
Subsoil	Yellowish brown or brown silt loam friable, often stratified, no mottling and little or no concretionary material above 36".	Light brown or yellowish brown silt loam; often with concretionary material; below 14" to 24" light gray or bluish gray mottled with yellow and brown; contains concretions; often stratified.	Light gray, gray, or bluish gray, silt loam, often mottled with brown sandy or gravelly material present within 42".
Parent Material	Recent alluvium from mixed loess and coastal plain materials.	Recent alluvium from mixed loess and coastal plain materials.	Recent alluvium from mixed loess and coastal plain materials.
Natural Drainage and Profile Number	Good—4	Fair—3	Very poor—1
Series Name	SHANNON	HYMON	BEECHY
Important Textures	Silt loam, loam, gravelly loam, fine sandy loam, sandy loam, gravelly loamy sand	Silt loam, loam, gravelly loam, sandy loam, gravelly loamy sand	Silt loam, sandy loam, gravelly sandy loam
Remarks	Similar to Vicksburg but containing coastal plain materials.	Similar to Collins, but containing coastal plain materials.	Similar to Waverly, but containing coastal plain materials.

III. FIRST BOTTOM SOILS

2. From Loess and Coastal Plain Materials

IDENTIFICATION DESCRIPTIONS:—Continued

III. FIRST BOTTOM SOILS

3. From Sandstone and Shale Materials

Usual Topography	Level	Level	Level
Surface Soil	Light brown silt loam, often containing appreciable amount of fine and very fine sand; slightly acid.	Grayish brown to light brown silt loam; acid.	Gray silt loam, sometimes mottled with brown; strongly acid.
Subsoil	Yellow to yellowish brown friable silty clay loam to silty clay; may be stratified; little or no mottling above 36".	Yellow, yellowish brown, or brown silty clay loam to silty clay, mottled with gray and rust brown below 15-18".	Gray silty clay loam to silty clay with yellow, brown, and rust brown mottlings.
Parent Material	Recent alluvium from sandstone and shale uplands.	Recent alluvium from sandstone and shale uplands.	Recent alluvium from sandstone and shale uplands.
Natural Drainage and Profile Number	Good—4	Fair—3	Very poor—1
Series Name	POPE	PHILO	ATKINS
Important Textures	Silt loam, loam	Silt loam	Silt loam, silty clay loam
Remarks	Previously mapped much more widely in Ky. in respect to drainage.	Occurs widely, previously included with Atkins, Pope, or Holly.	

III. FIRST BOTTOM SOILS

3. From Sandstone and Shale Materials

IDENTIFICATION DESCRIPTIONS—Continued

III. FIRST BOTTOM SOILS

4. From Pure or Mixed Limestone Materials

Usual Topography		Level	Level	Level	Level
Surface Soil	Brown or dark brown silt loam, slightly acid to slightly alkaline.	Brown to dark brown silty clay loam, usually slightly acid.	Brown to grayish brown silt loam, slightly acid to slightly alkaline.	Gray silt loam, sometimes mottled with dark gray and rusty brown; acid.	Dark brown or very dark gray to black silty clay loam, acid.
Subsoil	Light brown heavy silt loam or silty clay loam, with little or no color change to 36"; no mottling; texture somewhat variable in places.	Light brown, brown, or dark brown heavy silty clay loam or clay loam, tough and compact. Iron concretions common in subsoil, but little or no mottling above 36".	Brown to grayish brown, silty clay loam; below 15" mottled brown, dark gray, rust brown, and light gray; may be compact.	Dark gray, yellow, and rust brown mottled tough silty clay loam or silty clay; below 12"-15" mottled bluish gray and yellow containing dark concretionary material.	Yellowish clay mottled with bluish gray and yellowish brown, or bluish gray plastic clay containing yellowish brown and black concretions in places.
Parent Material	Recent alluvium from uplands of pure or mixed limestone origin.	Recent alluvium from uplands of pure or mixed limestone origin.	Recent alluvium from uplands of pure or mixed limestone origin.	Recent alluvium from uplands of pure or mixed limestone origin.	Recent alluvium from uplands of pure or mixed limestone origin.
Natural Drainage and Profile Number	Good—4	Medium—4-3	Fair—3	Very poor—1	Very poor—7
Series Name	HUNTINGTON	EGAM	LINDSIDE	MELVIN	DUNNING
Important Textures	Silt loam, silty clay loam, very fine sandy loam, loam	Silty clay loam, loam	Silt loam, silty clay loam	Silt loam, silty clay loam	Silty clay loam
Remarks		Differs from Huntington soils chiefly in having a heavier subsoil.	Occurs extensively, but not yet mapped in Ky.; comprises large part of Holly and a smaller part of Huntington, as previously mapped in Ky.	Previously mapped as Holly, now correlated as Melvin.	Differs from Burgin in being alluvial rather than upland depression soil; also, usually contains less organic matter and is acid in reaction.

III. FIRST BOTTOM SOILS

4. From Pure or Mixed Limestone Materials

IDENTIFICATION DESCRIPTIONS'—Continued

IV. COLLUVIAL SOILS

1. Local Wash in Sinks of Mississippian Limestone Uplands

Usual Topography	Depression	Depression	Depression
Surface Soil	Red, reddish brown, or brown friable silty clay loam; slightly acid.	Yellowish brown to brownish gray friable silty clay loam; acid.	Gray floury silt loam; acid.
Subsoil	Reddish brown or yellow brown silty clay loam or clay; little or no mottling above 36".	Slight reddish brown, yellow brown, or yellow silty clay loam or clay; mottled with brown, gray, drab, or lemon yellow below 14" to 24". Small black soft crumbly iron concretions in lower subsoil.	Predominantly gray silty clay loam mottled with yellow, orange, blue-gray, or rust brown. Compact silty or heavy plastic layers occur. Concretions and concretionary material usually abundant.
Parent Material	Alluvium and colluvium from Mississippian limestone uplands.	Alluvium and colluvium from Mississippian limestone uplands.	Alluvium and colluvium from Mississippian limestone uplands.
Natural Drainage and Profile Number	Good—4	Fair—3	Very poor—1
Series Name	ABERNATHY	OOLTEWAH	GUTHRIE
Important Textures	Silty clay loam, silt loam	Silty clay loam, silt loam	Silt loam
Remarks	Occupies sinkholes and solution basins; may be alluvial, colluvial, or both.	Not yet mapped in Ky.; previously included with Abernathy.	Mapped also as very poorly drained (1 profile) member of all upland catenas derived wholly or in part from limestone.

IV. COLLUVIAL SOILS

1. Local Wash in Sinks of Mississippian Limestone Uplands

IDENTIFICATION DESCRIPTIONS—Continued

IV. COLLUVIAL SOILS

2. Principally from Loess Materials

Usual Topography	Gently undulating	Gently undulating	Very gently undulating
Surface Soil	Light brown, smooth mellow silt loam slightly acid.	Grayish-brown to light brown, smooth silt loam, acid.	Gray to grayish-brown silt loam, acid.
Subsoil	Yellowish-brown or brown, friable silt loam with no mottling or concretions above 36".	Light brown to light yellowish-brown, becoming lighter colored and mottled in the lower subsoil, concretions also present.	Gray to bluish-gray silt loam to silty clay loam, mottled, considerable concretionary material present.
Parent Material	Colluvium and alluvium from loess uplands.	Colluvium and alluvium from loess uplands.	Colluvium and alluvium from loess uplands.
Natural Drainage and Profile Number	Good—4	Fair—3	Poor—1
Series Name	Tigrett	Briensburg	Dyer
Important Textures	Silt loam	Silt loam	Silt loam

Remarks

These three soils occur as gently sloping areas at the base of hills, as gently sloping alluvial fans of small streams in flood plains of larger streams, or as narrow U-shaped bottoms along deeply entrenched streams, and are similar respectively to Vicksburg, Collins, and Waverly.

APPENDIX**Miscellaneous Soils****Clarksville**

Mapped in Warren County, Kentucky, 1904, to include all Mississippian limestone soils of western Kentucky. Now held to a very cherty Mississippian limestone soil having a gray surface and shallow yellow subsoil overlying chert beds. As such, its occurrence in Kentucky is doubtful except possibly in a few places as a variation in Bodine. The old Clarksville is now covered by the series Bodine, Baxter, Hagerstown, Decatur, Russellville, Dickson, and Guthrie in accordance with the key.

Colbert

Named in the Garrard County, Kentucky, survey, 1921, and described as a poorly drained soil of cherty limestone origin, but included with Lebanon due to the small size of the areas found. It was previously mapped in Jessamine County, Kentucky, as a soil of much better drainage, probably Lowell. At present, Colbert is mapped as a poorly drained limestone soil associated with Talbott, both having very heavy subsoils. As such, it has not been recognized in Kentucky.

DeKalb

Previously mapped to include more or less all rough land of sandstone and shale origin. Now confined to well-drained sandstone and shale soil having a definite podsolized layer in the surface, and, as such, is no longer mapped in Kentucky. Soils once mapped in Kentucky as DeKalb are mostly Muskingum, with some Hanceville, Hartsells, and other sandstone and shale soils appearing in the key.

Elkton

Mapped as poorly drained bottom soil in Mason County, Kentucky, in 1903. At present, would probably be mapped as Melvin or Ginat. Elkton is now held to a poorly drained soil of coastal plain origin.

Holly

Previously mapped in Kentucky as poorly drained first bottom of sandstone and shale, limestone, or mixed limestone, sandstone, and shale origin. Now held to a poorly drained first bottom soil derived from glaciated sandstone and shale materials. Superseded in Kentucky by Melvin, Atkins, Lindside, and Philo in accordance with the key.

Leonardtown

Mapped in Mason County, Kentucky, 1903, as an Ohio River gravelly terrace, and as such, would now probably be superseded by Wheeling, Sciotoville, and Ginat. Leonardtown is now held to a coastal plain soil of fair drainage.

Meadow

Mapped in Mason County, Kentucky, 1903, to denote poorly drained bottom land derived from mixed limestone materials. Superseded in Kentucky by Melvin. Meadow is no longer used as a soil series name.

Miami

Mapped in Union County, Kentucky, 1902, to denote well-drained upland soils, some of sandstone and shale origin and some of loess origin. Superseded in Kentucky by Memphis and Hanceville catenas. Miami is now confined to a well-drained glacial soil of the Late Wisconsin Drift.

Norfolk

Mapped in Mason County, Kentucky, 1903, as a sandy terrace along the Ohio River, and as such, would probably now be classed with the Wheeling catena of soils. Norfolk is now confined to a well-drained upland soil of coastal plain origin.

Pennington

Mapped in Rockcastle County, Kentucky, 1910, as small areas of clay soil of poor drainage derived from Pennington calcareous shales and thin-bedded limestones. None has been mapped since 1910, and the true correlation has not been established at present. Probably most of this series would now be mapped as Lebanon or Lawrence.

Sharkey

Mapped in Union County, Kentucky, 1902, as a first bottom "gumbo" and "buckshot" soil. There is difference of opinion as to the geographical range of the Sharkey series, hence it has been excluded from the key for the present. Soils mapped in Union County as Sharkey may possibly be Melvin or Atkins.

Sturgis

Mapped in Union County, Kentucky, 1902, as a sandy terrace, in the vicinity of Sturgis. The name is now in disuse, and the soil it represented possibly belongs in the Dexter or Wheeling catenas.

Yazoo

Mapped in Union County, Kentucky, 1902, over a variety of bottom land and terrace conditions along the Ohio River, and, as such, it can no longer be correlated. The soil series of the Huntington and Wheeling catenas probably cover the soils of the old Yazoo series as mapped in Union County.

